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REPORT FOR THE CONFERENCE ON POLLUTION OF RARITAN BAY AND ADJACENT INTERSTATE WATERS. THIRD SESSION. VOLUME I. PROJECT STUDIES AND RESULTS

Federal Water Pollution Control Administration
Metuchen, New Jersey

May 1967

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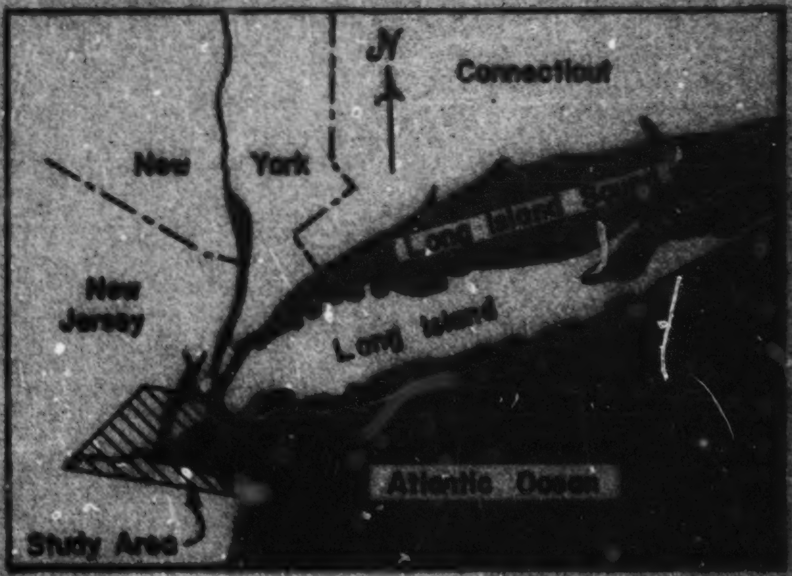
REPORT
for
THE CONFERENCE ON POLLUTION OF RARITAN BAY AND ADJACENT INTERSTATE WATERS

THIRD SESSION

VOLUME I–PROJECT STUDIES AND RESULTS


N
Connecticut
New York
New Jersey
Long Island Sound
Long Island
Atlantic Ocean
Study Area

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NORTHEAST REGION - RARITAN BAY PROJECT
METUCHEN, N.J.
MAY 1967

REPORT

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U.S. DEPARTMENT OF THE INTERIOR
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INTRODUCTION

Purpose and Scope

In 1961 the Surgeon General of the Public Health Service, under the provisions of the Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.), called a conference on the pollution of the interstate waters of Raritan Bay and adjacent waters. As a result of this conference the Public Health Service established the Raritan Bay Project to undertake a study of these waters to provide scientific data on which further pollution control programs could be established.

Raritan B

This report presents results of Project studies which included the following activities:

1. Intensive bacteriological sampling of Raritan Bay and shoreline, Arthur Kill, Kill Van Kull, Upper Bay, Raritan River and wastewater treatment plants discharging to study area waters.

2. Intensive chemical sampling of these same waters and wastewater treatment plants to determine dissolved oxygen concentrations, biochemical oxygen demands, chemical oxygen demands and nutrient levels — nitrites, nitrates and phosphates.

3. Intensive biological sampling in these waters to determine biological communities of phytoplankton, zooplankton and benthic organisms as they are related to pollution.

4. Current and dispersion studies to trace water movements in Raritan Bay and movements from the Arthur Kill, Raritan River and the Narrows into the Bay.

5. Detailed wastewater treatment plant surveys and sampling programs to determine operating efficiency. Surveys included an evaluation of the condition of equipment, effectiveness of operation and maintenance, and the qualifications of plant operators.

6. Detailed surveys of industrial operations including a review of data collected by other agencies, plant visitations, and sampling programs to evaluate treatment efficiencies and measure contaminants discharged.

7. Survey of commercial fishing and the quality and quantity of shellfish in Raritan Bay to determine the present condition of these industries and their future potential.

8. Investigation of the present and potential use of the study waters for recreational bathing, boating and fishing.

9. Study of the pollution effects of commercial shipping and recreational boating in the area.

10. Establishment of a series of automatic water quality monitoring stations to provide a measure of the quality of the waters entering Raritan Bay.

11. Review of field and laboratory data to determine the effects of stormwater overflows on present water quality.

12. Study to determine the effectiveness of chlorination of wastewater treatment plant effluents in reducing bacteria populations in Raritan Bay.

13. Determination of the municipal and industrial wastes load discharged to Arthur Kill.

14. Investigation of the geology of Raritan Bay to provide further data on water movement in the study area.

15. Study to determine the absence or presence of known pathogenic, or disease causing bacteria, in Raritan Bay waters and in shellfish taken from various locations throughout the estuary.

Project History

The Federal Water Pollution Control Act as amended (33 U.S.C. 466 et seq.), provides that pollution of interstate waters which endangers the health or welfare of any person is subject to abatement under procedures described in Section 10 (33 U.S.C. 466 g) of the Act.

The first step of this procedure is the calling of a conference which brings together state and interstate water pollution control agencies, the Public Health Service and other interested parties having jurisdiction in the area. The purposes of such a conference are to review the existing situation, to lay a basis for future action by all parties concerned, and to give states, interstate agencies, localities and industries an opportunity to take any indicated remedial action under state and local law.

On the basis of reports, surveys and studies the Surgeon General of the Public Health Service, having reason to believe that pollution of the interstate waters of Raritan Bay and adjacent waters — caused by discharges of untreated and inadequately treated sewage and industrial wastes by municipalities and industries in New Jersey and New York — was endangering the health and welfare of persons in these two states, called a conference on August 22, 1961. Conferees present represented the New Jersey State Health Department, New York State Department of Health, Interstate Sanitation Commission and the Public Health Service.

At the first session, conferees unanimously agreed to the following conclusions and recommendations:

1. "The Raritan Bay and adjacent waters which are the subject of the conference are interstate waters within the meaning of the Federal Water Pollution Control Act.

2. "There is pollution of these waters.

3. "Scientific data, taking into account a wide range of factors and technological problems, including health, conservation, water policy and uses, and industrial processes are urgently needed, and are the critical issue in further control of these waters.

4. "The Public Health Service in collaboration with the New Jersey State Health Department, the New York State Department of Health, and the Interstate Sanitation Commission, will undertake an investigation and study of these waters to accumulate these data.

5. "Cognizance is taken of the programs and the administrative machinery of the agencies of the State of New York and the State of New Jersey, and the Interstate Sanitation Commission to control pollution of these waters.

6. "There has been, and continues to be, progress under plan in abatement of pollution of these waters.

7. "The conferees welcome and appreciate the interest, support and collaboration of the Public Health Service in the collective efforts to preserve the Raritan Bay and particularly in solving the scientific problems.

8. "The conferees are willing to report to the Public Health Service at appropriate intervals; the Public Health Service will report to the other conferees periodically.

9. "The conference will be reconvened on the call of the Chairman one year from the present date in order to evaluate the progress made by the study and investigation and to receive the recommendations of the conferees as to further action."

In accordance with the recommendations of the first conference the Public Health Service, Division of Water Supply and Pollution Control, secured, equipped and staffed a laboratory at Raritan Depot, Edison, N.J., to conduct water quality investigations. The objective of the Project was to develop the scientific data necessary for the conferees to establish an effective program for the abatement and control of pollution in the study area, which was defined to include Lower, Sandy Hook and Raritan Bays, a portion of the Narrows, Arthur Kill, the tidal reach of the Raritan River and other smaller tributaries to the above named waterways.

First phase of Project activities was the assembling of a staff and a review of existing data. Based upon this review a sampling program was designed which would permit an evaluation of the variations in water quality and long term trends. The program was initiated in August of 1962 and consisted of a 13-month sampling program of Raritan Bay, Arthur Kill and the municipal wastewater treatment plants discharging to these waters. Weekly samples were taken at each of the sampling stations within Raritan Bay and Arthur Kill. Simultaneously, samples were collected of the effluents from each of the major municipal treatment plants discharging to the Bay to permit an assessment of the relationship between waste load and water quality. In May 1963 the Project reported to the second session of the "Conference in the Matter of Pollution of Interstate Waters of Raritan Bay and Adjacent Waters (New York-New Jersey)." Presented at that session were all data generated by the Project from its inception to December 31, 1962. Among the activities initiated by the Project through that reporting date were:

1. Intensive bacteriological sampling program of Raritan Bay and shoreline, entrant waters, and wastewater treatment plants discharging to the Bay to determine bacterial densities.

2. Series of dissolved oxygen tests in Raritan Bay, and biochemical oxygen demand tests of wastewater treatment plant effluents.

3. Current and dispersion studies to trace water movements in Raritan Bay and movements from the Arthur Kill into the estuary.

4. Biological investigation to define the area of biological concern for purposes of further studies.

Conferees at the second session agreed to the following conclusions and recommendations:

1. "The States of New Jersey and New York and the Interstate Sanitation Commission have active and effective programs for the control and abatement of pollution of the waters of Raritan Bay and adjacent waters as evidenced by:

   a. "With respect to waters other than those originating in the Arthur Kill and coming through the Narrows, the New Jersey communities have been steadily improving treatment since the 1940's. At the present time, all domestic waste from New Jersey discharging into the Hudson River and upper New York Bay area have been intercepted for treatment except for a portion of Weehawken and Union City, where the construction of needed facilities is nearing completion. On the New York side, New York City, pursuant to a consent order of the Interstate Sanitation Commission dating from 1957 has been engaged in a large program of construction. The Hunts Point and Coney Island projects have been completed. Under construction are the pollution control projects of Newton Creek and Jamaica Bay. Scheduled for early construction, pursuant to the consent order, are projects at Red Hook, Port Richmond, North River and Ward's Island. On these projects as well as those mentioned subsequently the work is done pursuant to the approval of Plans and specifications by the New Jersey and New York State Health Departments.

b. "Entrant waters from the Raritan River were improved by completion in 1958 of the Middlesex County Sewerage Authority Treatment Plant. The New Jersey Health Department and the Authority have a continuing program on further abatement of pollution of the Raritan River.

c. "In the Arthur Kill intensive research and investigations by New York, New Jersey and the Interstate Sanitation Commission have been underway since 1957. As a result of information has recently become available which has formed the basis for the issuance of eight orders by the State of New Jersey as follows: Elizabeth Joint Meeting, Rahway Valley Sewerage Authority, Linden-Roselle Sewerage Authority, Borough of Carteret, Woodbridge Township, Humble Oil and Refining Company, American Cyanamid, General Aniline and Film Company; and three by New York authorities as follows: Procter and Gamble, Nassau Smelting and Refining Company and the Willowbrook State School.

d. "In Raritan Bay, pursuant to an administrative order and a timetable agreement with the Attorney General of the State of New Jersey, construction of needed works at Keyport was already underway prior to the first session of this conference, and was completed in 1962. At Atlantic Highlands, Highlands, Keansburg, Union Beach, Borough of Matawan and two industrial installations, steps of either engineering or a legal nature are in progress. The Borough of Highlands is installing an automatic chlorine residual analyzer and recorder with an alarm system and is also planning to repair the outfall line which would take the effluent from Raritan Bay and discharge it to the Atlantic Ocean. The borough of Atlantic Highlands has hired an engineer to prepare preliminary studies to enlarge the present facilities by 50 percent and has applied for Housing and Home Finance Agency planning funds. In addition the Borough is planning to install a chlorine residual analyzer and recorder with an alarm system. The Borough of Keansburg has planned for additions and alterations to this plant and they have been approved by the State Department of Health. The Borough plans to advertise for bids soon. In Union Beach a certificate of necessity has been issued to allow this community to exceed bonded indebtedness limitations. Preliminary plans have been approved by the State Health Department for a sewage system and treatment plant. The Borough of Matawan has completed construction of a new plant which was placed in operation during the last week of April 1963. Construction of a new treatment plant by the Madison Township Sewerage Authority is nearing completion with a scheduled completion date of May 1963. Plans for proposed expansion to increase the capacity of the Middlesex County Sewerage Authority plant are scheduled to be completed by the latter part of 1963. The International Flavor and Fragrances Company hired an industrial waste engineer to develop treatment facilities. A feasibility report has been furnished. Pollution sources of the B. Zura Chemical Company have been eliminated by the closing of the plant.

"For the New York waters concerned, the State Department of Health has completed classification studies and report covering the subject waters. Arrangements are now being made for public classification hearings to be held in New York City during the months of June or July. Actual classification will be made by the Water Resources Commission of New York State. The classifications of the Interstate Sanitation Commission for these waters have been in force for over twenty years.

2. "The Public Health Service, in collaboration with the New Jersey State Department of Health, the New York State Department of Health, and the Interstate Sanitation Commission will continue and complete the investigation and study of the Raritan Bay and adjacent waters in accordance with the recommendations of the conferees at the first session of the conference held on August 22, 1961."

In accordance with recommendations of the second session, the Public Health Service continued its studies to define the type of pollution problems existing in the interstate waters of Raritan Bay and adjacent waters. The already established intensive study program, which involved determination of specific pollutants and their concentration, and methods of securing the best possible water quality, continued through September 1963. At the conclusion of this sampling period the Project adopted a surveillance program consisting of monthly samplings at selected stations throughout the study area as well as at wastewater treatment plant discharges. The change to a surveillance operation was accompanied by the initiation of Project studies in special subject areas found necessary as a result of the previous investigations. Such studies, initiated in September 1963 and continued through January 1966, were to evaluate and ascertain information on such items as water movement through the Bay; the presence or absence of specific pathogenic organisms in Bay waters and in shellfish; an evaluation of the shellfish quality and probable harvest value; surveys of industrial wastes discharges; and surveys of various water uses and their effects upon water quality, including studies of commercial and recreational fishing, commercial navigation, recreational boating and bathing.

STUDY AREA

General Description

The Project study area encompasses three major bodies of water, all located within the New York Metropolitan area. The estuary, collectively referred to in this report as Raritan Bay, is further divided into three general areas--Raritan Bay in the western and southern area, Lower Bay in the north and Sandy Hook Bay in the southeast. The estuary is triangular in shape and opens eastward to the Atlantic Ocean. It is divided roughly into two equal portions by the New York-New Jersey state line as shown in Figure 1.

The second major body of water included in the Project study area is the Arthur Kill, a tidal strait which connects the western end of Raritan Bay estuary with Newark and Upper Bays via the Kill Van Kull in the north. (See Figure 1) The Project also investigated a reach of the Raritan River, the major fresh water tributary to the Bay, from its mouth to the junction of the Millstone River in Manville, N.J. (See Figure 2)

This report, for purposes of presentation and evaluation of data, assumes the mouth of the Raritan River as being located at the New Jersey Central Railroad bridge between Perth Amboy and South Amboy, N.J.; and the southern limit of the Arthur Kill as being the Outerbridge Crossing between Perth Amboy, N.J., and Staten Island, N.Y.

Physical Features

Raritan Bay and Arthur Kill collectively have a water surface area of 93 square miles and a water volume of 38 billion cubic feet, both at low water. Table I presents additional physical measurements of the Bay and Kill. The shorelines of Raritan Bay, amounting to 43 miles exclusive of the Arthur Kill, are relatively straight. Sea cliffs and wide beaches, as well as tidal marshes, indicate the Bay has reached early maturity in the cycle of shoreline development along submergent coasts.

The estuary is relatively shallow, with a mean depth of less than 15 feet, excluding the Arthur Kill. The floor of Raritan Bay slopes fairly uniformly and gently toward the center where the maximum depth is about 30 feet, excluding the commercial shipping channels which have depths to 40 feet. The floor of the estuary consists of sands and silts, comprising four separate sediment bodies.

The Arthur Kill has a shoreline of 36 miles in New York and New Jersey and a calculated mean depth of 18 feet. The Kill is characterized by a narrow commercial shipping channel of 35 feet depth throughout its entire length.

TABLE I

PHYSICAL DATA FOR RARITAN AND LOWER BAYS AND ARTHUR KILL

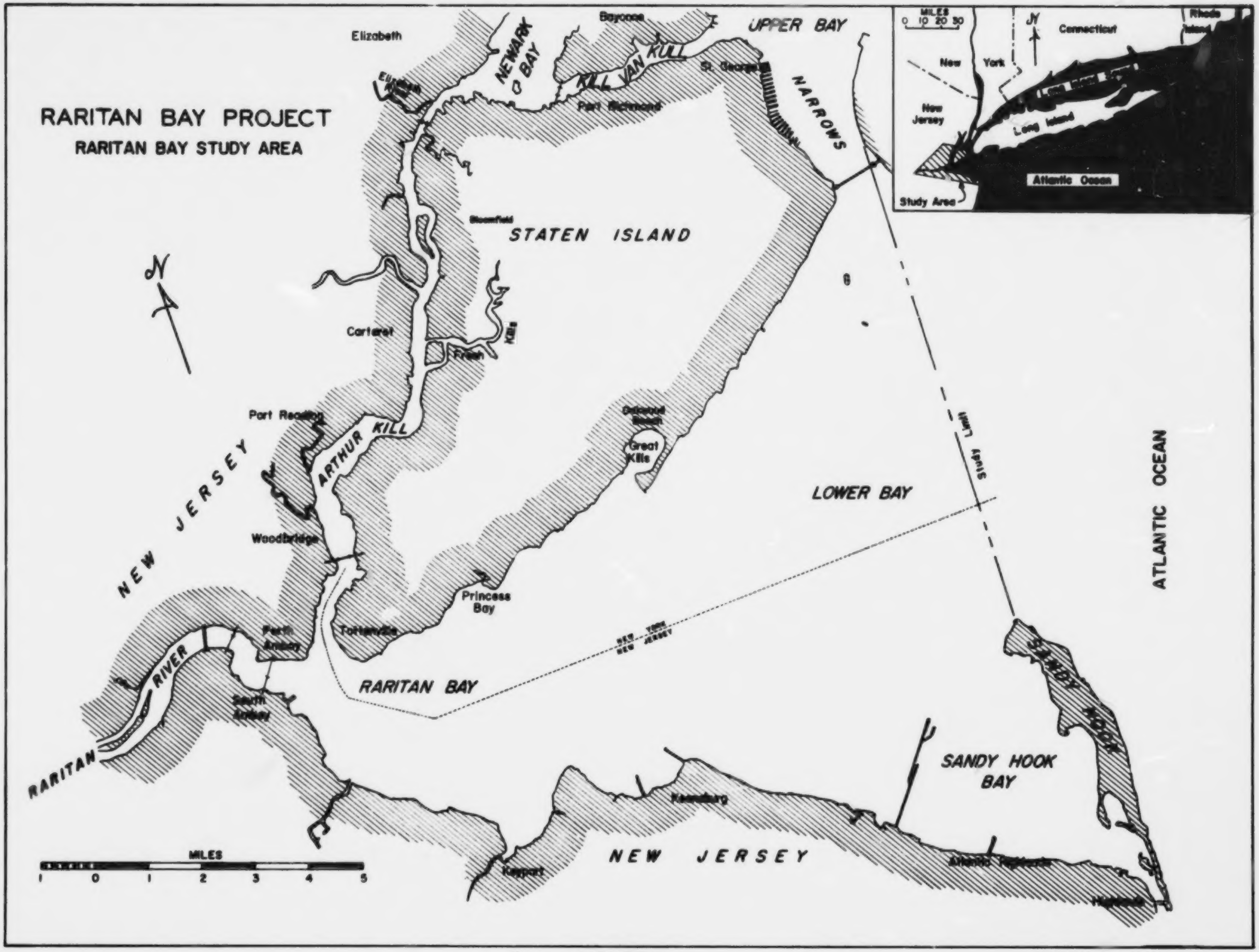
Area	Volume (Billion cubic feet)		Surface Area (Square Miles)	Mean Depth (Feet)	Shore Line (Miles)		
	(Low Water)	(High Water*)	(Low Water)	(Vol. ÷ Surf. Area)	Staten Is.	New Jersey	Total
Raritan Bay	10.4	14.8	31.82	11.75	11.18	13.00	24.18
Lower Bay (Inc. Sandy Hook Bay)	25.4	33.2	56.39	16.18	5.98	13.00	18.98
Raritan, Lower and Sandy Hook Bays combined	35.8	48.1	88.24	14.55	17.16	26.00	43.16
Arthur Kill	2.23	2.83	4.36	18.38	17.78	18.59	36.37
Total Study Area **	38.03	50.93	92.60	-	34.94	44.59	79.53

*Taking mean tidal range as 5 feet

**Excluding Raritan River

RARITAN BAY PROJECT

RARITAN BAY STUDY AREA



Elizabeth
Elizabeth River
NEWARK BAY
Bayonne
KILL VAN KULL
Port Richmond
St. George
UPPER BAY
NARROWS
Bloomfield
STATEN ISLAND
Carteret
Fresh Kills
Port Reading
ARTHUR KILL
Woodbridge
Oakwood Beach
Great Kills
Princess Bay
Tottenville
Perth Amboy
South Amboy
RARITAN RIVER
NEW JERSEY
RARITAN BAY
NEW YORK
NEW JERSEY
LOWER BAY
Study Limit
ATLANTIC OCEAN
SANDY HOOK
SANDY HOOK BAY
Keansburg
Keyport
NEW JERSEY
Atlantic Highlands
Highlands
N
MILES
1 0 1 2 3 4 5
MILES
0 10 20 30
N
Connecticut
Rhode Island
New York
New Jersey
Long Island
Atlantic Ocean
Study Area

FIGURE I

GPO 955-949

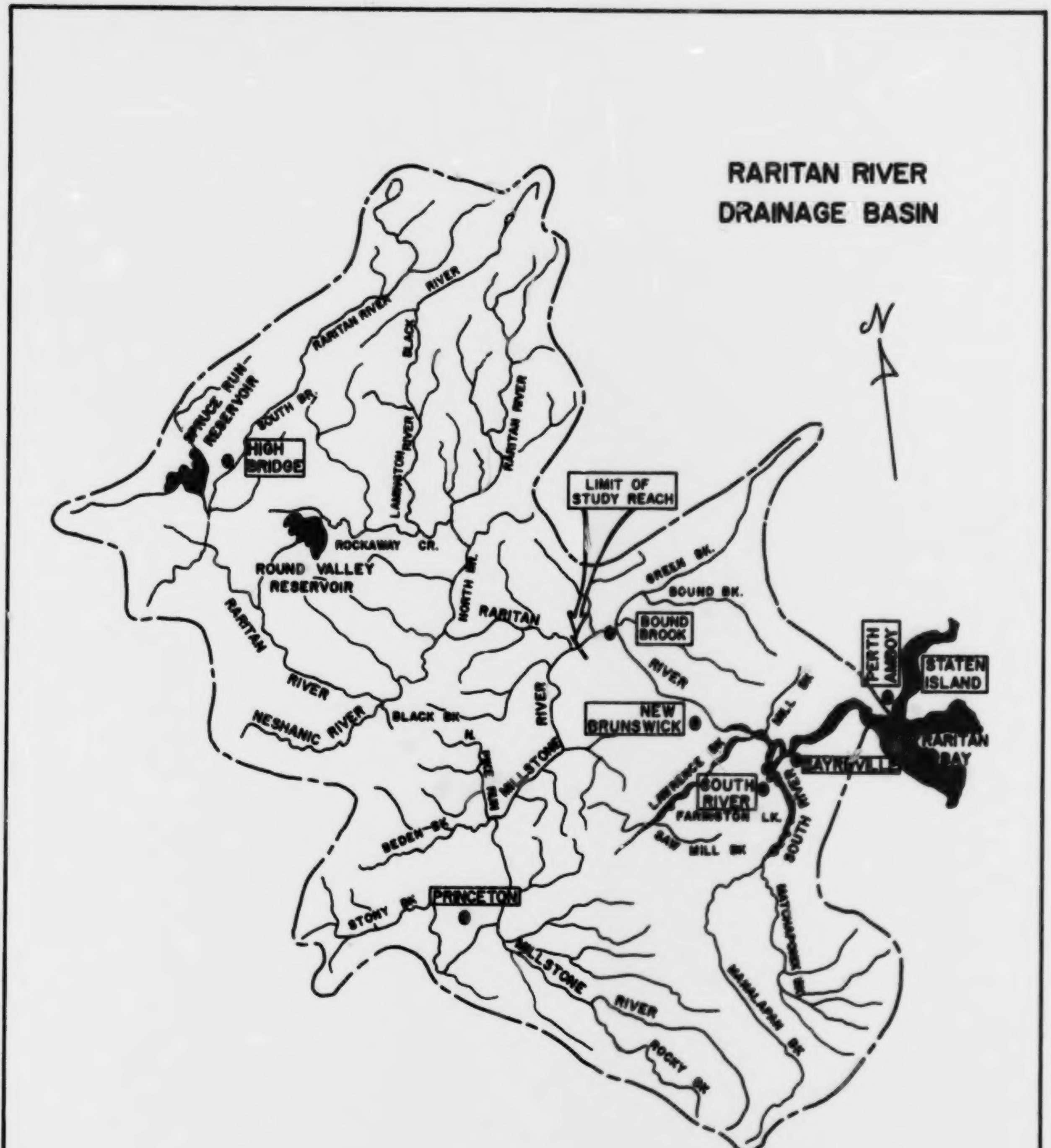

RARITAN RIVER
DRAINAGE BASIN
N
SPRUCE RUN RESERVOIR
HIGH BRIDGE
SOUTH BR.
RARITAN RIVER
RIVER
BLACK
LAMINGTON RIVER
RARITAN RIVER
ROCKAWAY CR.
ROUND VALLEY RESERVOIR
NORTH BR.
RARITAN
LIMIT OF STUDY REACH
GREEN BK.
BOUND BK.
BOUND BROOK
RIVER
PERTH AMBOY
STATEN ISLAND
MILL BK.
RARITAN RIVER
NESHANIC RIVER
BLACK BK.
RIVER
NEW BRUNSWICK
RARITAN BAY
SAYREVILLE
N. BEE RUN
MILLSTONE
LAWRENCE BK.
SOUTH RIVER
FARRINGTON LK.
SAW MILL BK
SOUTH RIVER
BEDEN BK.
STONY BK.
PRINCETON
MATCHAPONIX BK.
MILLSTONE RIVER
MANALAPAN BK.
ROCKY BK.
MILES
5
0
5
10
15
20
25

FIGURE 2

The reach of the Raritan River included in the study area extends a distance of 21 miles from its mouth at Raritan Bay to the junction of the Millstone River. Above this confluence the Raritan River is a potable water supply. Fieldville Dam, 17 miles above the mouth, creates a small pool extending upstream of this point, and is the upstream limit of tidal influence. The 12 miles of waterway from Raritan Bay to New Brunswick, N.J., is navigable, with channel depths ranging from 25 feet below low sea level at Perth Amboy to nine feet below low sea level at New Brunswick.

Climatology

The climate of the study area, as characterized by New York City, is temperate with an average annual of 52°F. January and February, the coldest months, have a mean temperature of 31°F and July, the warmest month, has a mean of 73°F. Water temperatures generally follow a similar pattern, ranging from 0°C to 26°C. During summer months both air and water temperatures are suitable for a variety of water-based recreation, including bathing.

The average annual precipitation in the study area is approximately 42 inches, with heavier rainfall generally associated with the summer months. Precipitation during the Project study was generally below average as the entire northeastern area of the United States experienced severe drought conditions. Table II presents total precipitation and departures from normal for a number of weather stations in close proximity to Raritan Bay and Arthur Kill.

Prevailing winds in the study area are generally from the north and west. At Sandy Hook, N.J., almost 20% of the total wind duration is from the northwest; winds from the north and northeast each occur slightly more than 15% of the time.

Tides throughout the estuary are semi-diurnal and have a mean range varying from 4.3 feet at Fort Wadsworth at the Narrows to 5.3 feet at Tottenville, Staten Island, N.Y. The spring range at these locations is 5.2 and 6.4 feet respectively.

Hydrology

Raritan Bay and Arthur Kill receive water from adjacent saline bodies including the Atlantic Ocean, Upper and Newark Bays, and Kill Van Kull. As shown in Table I the Bay and Kill have a combined volume at low water of 38 billion cubic feet, of which the Kill comprises less than 6%. Volume at high water is estimated as 51 billion cubic feet, or 34% more than low water. Chloride concentration in the estuary ranges from 13,000 to 15,000 mg/l compared to a normal value for ocean water of 20,000 mg/l. Hence, the estuary is roughly two-thirds ocean water, with the balance representing fresh water inflow to the estuary.

TABLE II 1/

TOTAL ANNUAL PRECIPITATION AND DEPARTURES FROM NORMAL 2/

	1962		1963		1964		1965 3/	
Station	Prec.	Dep.	Prec.	Dep.	Prec.	Dep.	Prec.	Dep.
Flemington, N.J.	43.91	-1.40	36.23	-9.08	34.50	-10.81	27.11	
Freehold, N.J.	40.94	-5.09	33.89	-12.14	33.83	-12.20	28.80	
Long Valley, N.J.	44.95	-3.95	32.88	-16.02	26.43	-22.47	-	
New Brunswick, N.J.	40.27	-3.71	33.16	-10.82	34.62	- 9.36	23.75	
Plainfield, N.J.	45.27	-3.02	35.38	-12.91	39.93	- 8.36	28.69	
New Monmouth, N.J.	49.50	NA 4/	38.60	NA	-	NA	-	
Rahway, N.J.	37.01	NA	28.48	NA	36.62	NA	22.42	
Westerleigh, N.Y. (Staten Island)	44.77	NA	34.23	NA	37.66	NA	22.64	

1/ Source: U.S. Weather Bureau

2/ Normal rainfall based on period 1951-1960

3/ Incomplete - records for 10 months only

4/ NA: Data not available

The major fresh water input originates in the Hudson River Basin which discharges through Upper Bay in the Narrows into the easterly area of Raritan Bay. Ayers(1) in 1951 calculated that a net discharge of 6.0 billion cubic feet per tide leaves the Upper Bay system and enters Lower Bay through the Narrows. On the basis of salinity measurements Ayers further calculated that 0.7 billion cubic feet of fresh water moved through the Narrows into Lower Bay on each tide. Hence, the discharge through the Narrows must be recognized as a major source of water into Raritan Bay.

The natural fresh water drainage area of the Bay and Arthur Kill is approximately 1,300 square miles, including the basins of a number of tributary streams. The major tributaries are the Raritan and Shrewsbury Rivers which drain directly to the Bay, and the Elizabeth and Rahway Rivers which flow to the Arthur Kill. Table III presents data on USGS gaging stations on these streams, the calculated average run-off rate for each, and the total average fresh water discharge.

Total average fresh water runoff from these sources to Raritan Bay and Arthur Kill amounts to 2,000 cfs, more than 80% of which is provided by the Raritan River. Figure 2A presents a frequency curve for discharge at the Raritan River mouth extrapolated from the USGS 23-year record at Bound Brook, N.J.

During Project studies precipitation and stream runoff were below average. Examination of Geological Survey records for the water years October 1960 through September 1963 for the Raritan River indicates that the frequency distribution of runoff during this period was approximately 10% below normal. Hence, the severe drought which developed throughout the northeast during the latter phases of the study resulted in a reduction of fresh water inflow to the estuary and Kill below the average values.

In addition to the natural hydrographic sources a significant quantity of non-saline water is added to the estuary and the Arthur Kill by the discharge of raw and treated municipal and industrial wastes. Such sources average 650 cfs to the Arthur Kill and 105 cfs to Raritan Bay, which is equal to or greater than natural runoff from the Raritan River 30 to 55% of the time.

The Project study area is located directly adjacent to the New York metropolitan region, the most heavily populated area of the country. The census figures for 1955 and 1960, as well as projected populations made by the Metropolitan Regional Council for 1965, 1975 and 1985 for the United States as a whole, the New York metropolitan region and the five counties bordering Raritan Bay are as follows:

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(1) Cornell University Contract N6 onr 264, Task 15, Status Report #1

	Population in Millions				
	1955	1960	1965	1975	1985
United States	165	179	196	235	286
N.Y. Metropolitan Region	15	16	18	21	24
Five Counties*	1.4	1.6	2.2	3.2	4.3

*Richmond County (Staten Island), N.Y.; Middlesex, Monmouth, Somerset and Union Counties, N.J.

Use of study area waters is not limited to the five directly adjacent counties. Transportation facilities make it possible for a large portion of the New York metropolitan region to take advantage of the facilities of Raritan Bay. In particular, the construction of the Verrazzano-Narrows Bridge, connecting Brooklyn and Staten Island, N.Y., made it possible for large numbers of people residing in Brooklyn and Long Island to have ready access to the waters of the study area. Since the 1960 census, which indicated more than 2.6 million inhabitants in Brooklyn, N.Y., at least an additional 1.0 million persons are now within close proximity of the study area. Should this growth pattern continue through 1985 more than 5.0 million persons, located in the five counties adjacent to the Bay plus the western portion of Brooklyn, N.Y., will be conveniently located in and adjacent to the study area.

TABLE III

SUMMARY OF USGS STREAM GAGING STATION RECORDS, RARITAN BAY STUDY AREA STREAMS

Gaging Station Location	Drainage Area, mi^2	Average Discharge, cfs	Average Runoff Rate, cfsm
Raritan River Basin			
Raritan River, Bound Brook, N.J.	779	1,220	1.57
Green Brook, Plainfield,N.J.	9.8	12.1	1.24
Lawrence Brook, Farrington Dam, N.J.	34.4	38.5	1.12
South River, Old Bridge, N.J.	94.6	137	1.45
TOTALS	917.8	1407.6	
Extrapolated total average discharge:	1,072	1,650	
Arthur Kill Drainage Area			
Elizabeth River, Elizabeth, N.J.	20.2	23.8	1.18
Rahway River, Rahway, N.J.	40.9	44.8	1.10
Robinson's Branch, Rahway River, Rahway, N.J.	21.6	23.5	1.09
TOTALS	82.7	92.1	
Extrapolated total average discharge:		136	
Extrapolated total average discharge for total Arthur Kill drainage area:		160	

TABLE III (Cont'd)

SUMMARY OF USGS STREAM GAGING STATION RECORDS, RARITAN BAY STUDY AREA STREAMS

Gaging Station Location	Drainage Area, mi^2	Average Discharge, cfs	Average Runoff Rate, cfsm
Navesink-Shrewsbury River Basin			
Swimming River (head of Navesink River) near Red Bank, N.J.	48.5	77.2	1.59
New Jersey Shore Drainage Area	69	-	1.50*
Extrapolated total average discharge:		110	
Staten Island Shore Drainage Area	24	-	1.10*
Extrapolated total average discharge:		25	

* Estimated

PROBABILITY PLOT OF EXTRAPOLATED DAILY DISCHARGE DATA FOR RARITAN RIVER AT ENTRANCE TO RARITAN BAY
1904-08, 45-58, 60-63
DRAINAGE AREA 1072 SQ. MILES

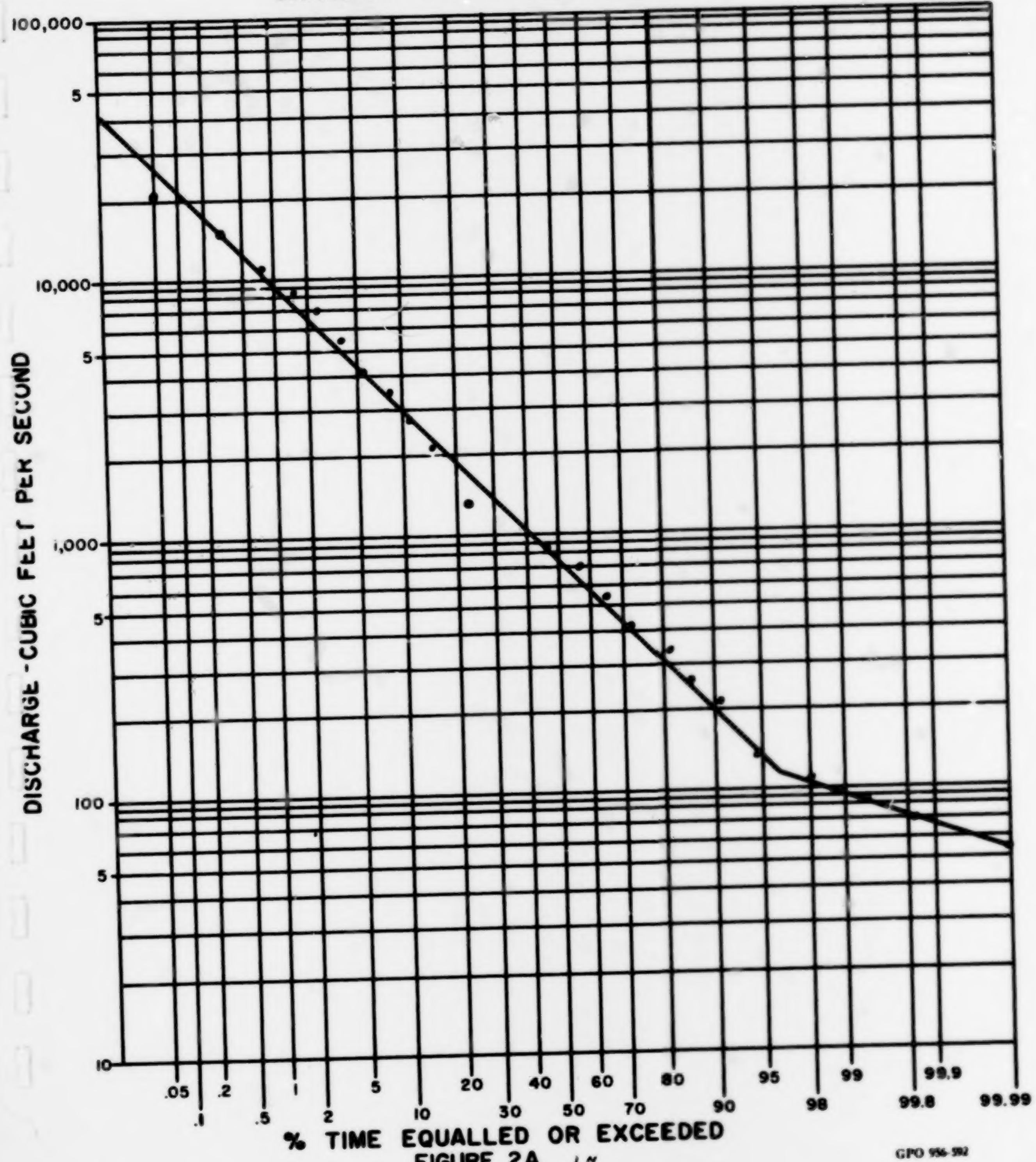

FIGURE 2A

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GPO 956-592

PRESENT AND FUTURE WATER USE

Nature and Value of Water Use

Demands of a large population directly adjacent to the study area result in a large variety of uses of Raritan Bay and Arthur Kill. These waters are presently, or have been in the past, used for such purposes as: Industrial water supply and navigation to meet the demands of the large commercial and industrial development in the area; commercial and shellfishing as a source of food for an expanding market; recreational boating, bathing, and fishing to provide adequate leisure for the large and increasing population; and a receiving body for raw and treated municipal sewage and industrial wastes.

Certain of these uses, in particular use as a receiving body for raw and inadequately treated wastes, prevent full development of other water uses as well as being in violation of existing legal standards established for these waters.

Studies were made to determine the magnitude of certain of these water uses. Where possible, present values of particular water uses were estimated. Possible future values associated with certain water uses, which are presently limited or restricted by inadequate water quality, were also forcasted. Table IV summarizes the results of these studies. Use of this water resource at the present time amounts to an estimated value of $2.0 million, 90% of which is associated with recreation. Development of suitable water quality within Raritan Bay could result in an ultimate value associated with the use of these waters of $19.0 million annually.

Certain water uses listed in Table IV were not assigned values since these uses would not be affected significantly by changes in water quality. Such uses include industrial water supply, commercial navigation, and the commercial blue crab industry.

Water Use Studies

Water Supply

There is no use made of the saline surface waters of the Raritan Bay study area for municipal water supply. Considerable use is made for industrial purposes, generally for cooling and condensing. Available information on industrial use by type of industry is shown in Table V and amounts to 1,300 MGD, 75% of which is utilized by the power generating industry.

TABLE IV

ANNUAL VALUES OF THE WATER RESOURCE OF RARITAN BAY

Water Use	Present Value	Potential w/Present Water Quality	Potential w/Suitable Water Quality	Increased Benefits From Improved Water Quality	Remarks
Water Supply					
Municipal	None	-	-	-	(Salinity-No Present Use)
Industrial	N/E	N/E	N/E	N/E	(1,300 MGD Cooling Water)
Commercial Navigation	N/E	N/E	N/E	Ins	(Water Quality has insignificant effect)
Commercial Fishery					
Hard Clam	$ 40,000	$ 250,000[1]	$ 3,850,000	$ 3,600,000	
Soft Clam	Ins	Ins	2/	2/	(Water Quality has insignificant effect)
Blue Crab	N/E	N/E	N/E	Ins	
Fin Fish	200,000	300,000	400,000	100,000	
Sub-Total	240,000	550,000	4,250,000	3,700,000	
Recreation					
Bathing	500,000	500,000	12,000,000	11,500,000	
Boating	760,000	760,000	1,500,000	740,000	
Fish & Waterfowl	468,000	468,000	1,468,000	1,000,000	
Sub-Total	1,728,000	1,728,000	14,968,000	13,240,000	
TOTAL ANNUAL VALUE	$1,968,000	$2,278,000	$19,218,000	$16,940,000	

Notes: N/E = Not Estimated Ins = Insignificant value

1. If suitable transplanting program is developed.
2. The Fish & Wildlife Service estimates that if a suitable market were available this industry could reach a value of $18,000,000 yearly.

Because of poor quality many industries provide pretreatment. In particular, the loss of cooling efficiency due to slime accumulations requires chlorination of the raw water. Hence, a reduction in the chlorine demand of the water would be of definite economic benefit, although no attempt was made to determine the magnitude of such benefits.

Commercial Navigation

The New York-New Jersey channel which traverses Raritan Bay is a vital part of the Port of New York, being used by about one-fourth of the ocean-going traffic entering or leaving the Port. In 1961, traffic in this channel amounted to nearly 120,000 vessel trips, 4,000 of which were made by vessels with drafts of 20 feet or more. Projections of future growth indicate that by the year 2015, annual traffic in this channel will increase to 200,000 vessel trips, 6,000 by vessels with draft of 20 feet or more.

TABLE V

INDUSTRIAL USES OF STUDY AREA WATERS[1]

Type of Industry	Water Use MGD	Major Use
Petroleum	250	Cooling; Condensing
Chemical	22	Cooling; Condensing
Smelting & Refining	37	Cooling; Condensing
Miscellaneous	2	Cooling
Power Generation	1,000	Cooling
Total	1,311 MGD	

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[1] Based upon available data from 1962 Industrial Waste Survey by Interstate Sanitation Commission and New Jersey State Department of Health. Does not include Raritan River.

No dollar value was assigned this use since it is not significantly affected by water quality.

Commercial Fishery

The commercial fin and shellfish industry was an important use of the water resource of Raritan Bay for many years. However, a combination of over-fishing and man-caused environmental changes, such as water pollution, has reduced the value of this use. A study by the Fish and Wildlife Service, U.S. Department of the Interior showed that the present shellfish resource in the Project area is limited to hard clams and blue crabs. The hard clam presently provides an annual harvest of only $40,000. The present standing crop, as estimated in a report by the Shellfish Sanitation Branch of the Northeast Research Center, Division of Environmental Engineering and Food Protection, Public Health Service (See Volume III - Appendices) amounts to over $35.0 million and could provide an annual harvest worth $3.85 million if water quality conditions were suitable. As an alternate, the Fish and Wildlife Service estimates that development of a successful transplanting and purification program could increase the harvest to $250,000 annually with present water quality. The soft clam resource, at one time significant but presently rated as of no significant commercial harvest, is estimated to have a potential commercial value of $18 million annually, assuming suitable water quality and market development. The blue crab commercial fishery appears to be affected only slightly, if at all, by water quality conditions. The 1960 New Jersey blue crab harvest, for example, was the second largest on record.

The Fish and Wildlife Service study estimated the present commercial fin fish harvest in Raritan Bay to have an annual value of $200,000. The industry trend to larger boats and more modern equipment could increase this harvest over a long term to $300,000 annually with present water quality. Improved water quality could raise the fin fish harvest to a potential value of $400,000 annually.

Recreation

The recreational uses of Raritan Bay by the large adjacent population take many forms including bathing, pleasure boating, sport fishing, recreational shellfishing and waterfowl hunting.

A Project study in 1963 of recreational bathing (See Volume III - Appendices) found 59 active bathing beaches on Raritan Bay and Arthur Kill. At several locations bacteriological analyses showed water quality below the recommended safe limits set by the regulatory agencies. The total number of bathers during 1963 was estimated at 1.07 million people. On the basis of the value of $.50 per bather day recommended by the Federal Joint Task Force on Recreation, the annual value of this resource use in 1963 was $500,000. Beach operators reported an income of $750,000 in 1963, with a total capital investment of $27.8 million at the time of the survey. Estimates of future population growth in the area indicate that with suitable water quality conditions the number of bathers could be increased to at least 16 million per year, with a value of $8.0 million annually.

In 1963 the Project also conducted a survey of recreational boating in Raritan Bay (See Volume III - Appendices). The survey found a total of 5,480 boats and yachts worth nearly $22 million berthed in or adjacent to the Bay. The industry realized a gross income of $2.5 million on a capital investment of $10.5 million. Employment in the industry amounted to 169 man years in 1963. Using a value of $1.50 per recreation day for boating as suggested by the Ad Hoc Committee on Water Resources, this water use had a value of $760,000 in 1963. The combined effects of increased population, higher income and more leisure and travel time in the surrounding area are expected to produce a rapid growth in recreational boating in Raritan Bay. By 1985, recreational boating will involve more than 1.0 million recreation days, worth an estimated $1.5 million annually.

The Fish and Wildlife Service investigated the value of recreational fin and shellfishing, crabbing and waterfowl hunting in Raritan Bay (See Volume III - Appendices). Based upon values of $1.50 per fisherman day and $1.00 per man day for recreational shellfishing, crabbing and waterfowl hunting, these uses of the water resource presently amount to $468,000 annually. The expected future population growth, coupled with improvements in water quality, could increase this benefit to an annual value of almost $1.5 million.

WATER QUALITY CAUSES AND EFFECTS

Water Temperature

Temperature has a direct effect upon the capacity of a receiving water to assimilate oxygen demanding wastes without nuisance. Increases in water temperature reduce the maximum amount of dissolved oxygen which the water can hold. In addition, the exertion of BOD is highly temperature dependent, with a more rapid demand upon oxygen taking place at higher stream temperatures.

Water temperature also can act as a limiting factor in the survival and propagation of various forms of aquatic life. The occurrence of certain biological phenomena such as algal blooms can be directly dependent upon suitable water temperatures.

Water temperatures within the study area are directly affected by the discharge of more than 2.0 billion gallons of hot cooling water from power generating stations. This thermal pollution is particularly critical in the Arthur Kill where limited circulation prevents adequate dissipation of the heat. A comparison of influent and effluent water characteristics from power generating stations has indicated the effluent to be as much as 15°F warmer than the incoming water. Analytical results reported for water temperature in the Arthur Kill indicate a warming of this waterway. It should be noted, however, that the sampling stations utilized were in the center of the channel; and therefore, higher water temperatures would be expected in the immediate vicinity of the discharge of heated wastes.

Dissolved Oxygen Relationships

Adequate levels of dissolved oxygen in water are necessary to provide an environment suitable for survival and propagation of fish and other forms of aquatic life. A lack of dissolved oxygen in industrial water supplies prevents the formation of the metallic oxides which reduce or prevent corrosion of process piping. Further, dissolved oxygen is necessary to stabilize organic and chemical wastes. When adequate levels of dissolved oxygen are not available in a receiving water to satisfy the imposed BOD and COD loadings, septic conditions result.

The amount of dissolved oxygen in a water depends on the rate of natural aeration or transfer from the atmosphere, photosynthesis, imposed oxygen demanding load, water salinity and temperature. In the areas covered by the Project water salinity and temperature are extremely important. With a chloride concentration of 15,000 mg/l and a water temperature of 26°C, only 7.0 mg/l of dissolved oxygen could be held by a water at 100% saturation. Such conditions of salinity and temperature have been observed in the study area, especially in the Arthur Kill. In order to provide at least 4.0 mg/l for a healthy fish habitat under such conditions a dissolved oxygen level of at least 57% saturation is required. The large oxygen demanding loads resulting from the discharge of raw and treated industrial and municipal wastes into the study area waters prevents dissolved oxygen levels from reaching this point. An additional oxygen demanding load is brought into the study area by pollution sources as far distant as Newark Bay and Upper Bay.

Arthur Kill analytical results indicate that this waterway contained 270,000 pounds BOD and 1.0 million pounds COD resulting from pollutional discharges. Project studies revealed that 250,000 lbs/day of BOD were discharged to the Kill by municipalities and industries. Industrial waste discharges contributed 190,000 lbs/day of COD. Thirty percent of the BOD and 85% of the COD loadings came from two industries —— Humble Oil and Refining Co., and General Aniline and Film Corp.

Raritan Bay receives 185,000 lbs/day of BOD, only 1.0% of which was attributable to industry. Nearly 90% of the total BOD load was found to be from one source —— Middlesex County Sewerage Authority.

Waste loadings to the Raritan River were estimated at 75,000 lbs/day of BOD, 98% of which is from industrial sources.

Dredging operations, while a necessary factor in the maintenance of navigational channels throughout the study area, and an important source of construction material for the metropolitan New York complex, impose an undetermined oxygen demanding load on these waters as a result of resuspension of organic matter from the bottom materials.

High pollution loadings result in critical dissolved oxygen levels in certain portions of the study area. In some portions of the Arthur Kill the oxygen demand exceeds the total available capacity of the water, resulting in conditions of zero dissolved oxygen over large stretches of the Kill. This low dissolved oxygen in the Kill is an important factor in the inability of the Arthur Kill to sustain a normal aquatic population.

Pollutional loads entering from the Raritan River and Arthur Kill lower the dissolved oxygen levels in the western portion of Raritan Bay, particularly during the summer and autumn period. Low dissolved oxygen levels are found in the northeastern area of Raritan Bay as a result of organic loads entering the Bay through the Narrows. An important factor in the maintenance of dissolved oxygen levels in the Bay is the photosynthetic production by a number of types of algae. The net yield to the waters serves to maintain satisfactory oxygen levels in much of the Bay.

In certain reaches of the Raritan River the imposed loadings result in a severe depletion of dissolved oxygen. During the summer of 1964 septic conditions were noted immediately upstream of the Fieldville Dam. The formation of floating mats and production of hydrogen sulfide gas rendered the stream unsuitable for recreation or other uses.

Nutrients

When other environmental factors such as temperature, sunlight and salinity are satisfactory, both nitrogen and phosphorus become critical nutrients for the growth of algae. These algae are desirable in limited quantities as a necessary link in the food chain which supports aquatic life. However, should eutrophication, or fertilization of the water with excess nutrients occur, algal growths may exceed desirable limits, and in some cases create nuisance blooms. Such blooms are unsightly, can result in obnoxious odors, and may result in a lowering of dissolved oxygen levels to below those needed for other forms of aquatic life.

Nitrogen and phosphorus are found in the discharge of municipal and industrial wastes regardless of the stage of normal treatment provided. The low nitrogen to phosphorus ratio reflects the influence of sewage discharged to these waters. In the Arthur Kill, and on occasion in Raritan Bay, the nitrogen to phosphorus ratio was less than 1. Such ratios indicate advanced eutrophication of the receiving water, which results in an abundance of plankton in both the Arthur Kill and Raritan Bay at certain seasons of the year. The profusion of the major algal types found in the Bay are related to specific nutrients supplied by municipal and industrial waste discharges.

The low dissolved oxygen values found during late spring and early summer in Raritan Bay are the result of a combination of two plankton populations which develop because of the advanced eutrophication of these waters. The decline of the winter-spring algal bloom reduces photosynthetic production of oxygen. Simultaneously, the planktonic population of active respirator animals reaches its peak. Hence, the low dissolved oxygen concentrations found during this period can be attributed, at least in part, to eutrophication of these waters which makes possible such changes in the plankton population.

Phenolic-Type Compounds

Phenolic-type compounds in water can result in tainting of fish flesh and shellfish meats, thus restricting legitimate use of the water for recreational fin and shellfishing. In addition, phenol can serve to inhibit the growth of aquatic organisms, as it is a widely used disinfectant.

Phenol pollution of a water may result from the discharge of municipal and industrial wastes; however it is commonly associated with petroleum wastes. High concentrations of phenol were found in those portions of the study area adjacent to petroleum manufacturers, in particular, toward the northern end of the Arthur Kill. Phenol content in the Kill was estimated as 6,000 pounds. A survey of industry indicated that nearly 11,000 lbs/day of phenol is discharged to the Kill, 98% of which emanates from three industries —— Humble Oil & Refining Co.,

E. I. duPont de Nemours-Grasselli, and General Aniline and Film Corp. The transport of phenols through the Arthur Kill and also through Upper Bay via the Narrows results in high phenol concentrations at the eastern and western extremities of Raritan Bay.

Analyses of shellfish meats taken from Raritan Bay indicated higher phenol concentrations in these meats than are found in shellfish taken from unpolluted waters. Uptake of phenols in growing waters taints t[illegible]at so as to render this food unsuitable for market. During Projec[illegible]s it was found that the majority of both recreational and co[illegible] fishing is done outside the limits of the study area because [illegible]ake of phenolic-type compounds and similar materials produced undesirable tastes in fish taken from Raritan Bay.

Oil and Grease

Oil and grease in a water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water. Such slicks may also interfere with the normal transfer of oxygen from the atmosphere into the water. Deposition of oil in the bottom sediments can serve to inhibit normal benthic growths, thus interrupting the aquatic food chain. Certain oils can produce a tainting of shellfish meats, thus rendering them unsuitable for use as food.

Oil and grease observed in Raritan Bay and the Arthur Kill are the result of the discharge of treated and untreated industrial and municipal wastes, spillage from dockside fueling and petroleum transfer activities, bilge pumping, and by spillage and engine exhaust from recreational boating.

In certain areas of the Arthur Kill the bottom sediment was heavily contaminated with oil and devoid of normal aquatic life. Shellfish meats taken from Raritan Bay showed contamination by mineral oils to levels greater than that encountered in shellfish from unpolluted waters.

Industrial wastes surveys revealed that more than 19,000 lbs/day of oil is discharged to the Arthur Kill. More than 90% of this is attributable to discharges from two plants —— Humble Oil & Refining Co. and General Aniline and Film Corp.

Bacteria Densities

Total coliform densities, as determined by the MPN test procedure, have traditionally served as an indicator of pollution. Most established standards relating to water use, both for internal consumption and for recreational exposure and contact, are based upon this indicator organism. The New York City Department of Health, for example, has established a maximum allowable total coliform MPN limit of 2,400 per 100 ml for recreational bathing.

While total coliforms are used as indicators of pollution, it is recognized that these organisms may originate from non-human sources. Hence, other indicator organisms such as the fecal coliform group are used to further identify possible human contamination. The presence of such organisms above certain acceptable levels is indicative of the presence of human wastes which may contain pathogenic organisms capable of causing disease in humans.

High bacterial densities were found in areas of the Bay influenced by discharges from the Arthur Kill, Raritan River and Upper Bay. High bacterial loadings at the junction of the Arthur Kill and Raritan River resulted in the closing of a public bathing beach in the City of Perth Amboy, N.J. Bacteria counts in excess of the maximum limits for bathing established by the New York City Department of Health were found at all but two sampling stations on the Staten Island shoreline from the Narrows to Tottenville. These high counts, combined with the results of dye studies which indicate that unchlorinated human wastes from Upper Bay reach Staten Island bathing beaches within six hours, indicate a definite health hazard to persons utilizing the waters of the Staten Island shoreline for recreational purposes.

In 1961 an epidemic of infectious hepatitis was traced to raw shellfish taken from Raritan Bay. Analyses of these shellfish showed high densities of pollution indicator bacteria in the meats, thereby indicating contamination from human sewage and confirming the hazard associated with the ingestion of raw shellfish meats. The majority of shellfish showing high bacteria counts were taken from those growing areas within the influence of the discharge of unchlorinated human wastes entering the study area through the Narrows.

Although high coliform counts indicate a potential health hazard to users of a water, such bacteria are not normally pathogenic. Isolation of pathogenic bacteria, such as _Salmonella_, is positive proof that a health hazard exists.

Salmonella were isolated from raw sewage discharged into Upper Bay immediately above the Narrows and also in the waters of the Narrows. _Salmonella_ of the same serotype were found in the waters of the easterly area of Raritan Bay and on the bathing beaches of Staten Island. The area of isolation coincides with the area shown by dye studies to be directly affected by Upper Bay.

Salmonella of the same serotype found in the Narrows and in the Bay water south of the Narrows were also found in shellfish meats taken from the eastern area of Raritan Bay. The presence of such organisms, which are capable of causing serious illness when present in a source of human food, further confirms the health hazard associated with the discharge of unchlorinated human excrement into Raritan Bay waters.

POLLUTION ABATEMENT PROGRAM

Enforcement Activities

Since the first session of the Conference of Pollution of Raritan Bay and Adjacent Waters, the State of New Jersey, City of New York and the Interstate Sanitation Commission have issued enforcement orders in an attempt to control pollution of the study waters. The following is a brief description of these orders and the latest known status of enforcement.

New Jersey State Department of Health

The New Jersey State Department of Health has issued abatement orders against a number of municipalities and industries as a result of previously existing regulations and of classification proceedings of the study area waters. The latest information available on the status of these orders is as follows:

1. Hatco Chemical Company, Division of W.R.Grace Co. - On December 21, 1962 orders were issued requiring pollution abatement by April 15, 1963. Early in 1966 the company became a participant in the Middlesex County Sewerage Authority. In April of that year the company began to make payments to the Authority for treatment services although the actual interceptor connection was delayed until November 1966 due to right-of-way negotiations. This facility is still discharging contaminated cooling waters to the Raritan River.

2. Union Carbide, Plastics Division - A pollution abatement order was issued July 14, 1942 against the predecessor corporation, Bakelite. The Union Carbide Corporation is reported to have a continuing program of investigation and isolation of sources of pollution from the stormwater and cooling water systems, and to have initiated a feasibility study for diversion of stormwater for treatment by filtration, chlorination and chemical treatment. By early 1967 the majority of plant wastes, exclusive of contaminated cooling waters, was treated by the Middlesex County Sewerage Authority.

3. Stabilized Pigments, Inc. - A pollution abatement order of December 21, 1962 required this company to complete its program by April 15, 1963. In April 1966 the company was placed under a court order restricting plant operations due to air pollution problems. Further enforcement of water pollution abatement orders have been held in abeyance pending a satisfactory conclusion of the air pollution problem.

4. General Aniline & Film Corporation - Pollution abatement orders were issued January 22, 1963 requiring control of pollution discharges by January 27, 1964. The company has met with the Health Department on a number of occasions to discuss its program. As of early 1967, this program has not been completed.

5. American Cyanamid Company (Linden) - Pollution abatement orders were issued January 22, 1963 calling for completion of a control program by January 27, 1964. In June 1964 the company advised the Health Department that the necessary equipment had been installed. The company program is to include barging of certain wastes to sea for ocean disposal. The necessary barge is under construction and scheduled to be placed in operation by July 1, 1967.

6. Reichhold Chemical Company (Elizabeth) - Pollution abatement orders were issued January 23, 1963 requiring completion of abatement activities by January 7, 1965. In June 1964 the firm advised the Health Department of plans to connect to municipal sewers owned by Elizabeth Joint Meeting. Connection to these sewers was completed in January 1966.

7. Humble Oil & Refining Company - Pollution control orders were issued January 22, 1963 requiring abatement by January 27, 1964. In April 1964 the firm indicated it had scheduled necessary activities for all work to be completed by the end of 1965. The sour water treatment facility, completed in late 1966, provides treatment to the largest BOD source in the plant. The west side chemical products separator has been completed. Spent caustic is now being loaded on barges and shipped for sale. As of early 1967, additional work to reduce pollution from this source was underway.

8. Philip Carey Manufacturing Co. - Pollution abatement orders were issued September 1, 1961 requiring the adoption of a program by December 1, 1961. The Health Department turned this case over to the Office of the State Attorney General for prosecution. In November 1966, a court order was issued requiring abatement by April 1967.

9. Hess Oil & Chemical Company - Pollution abatement orders were served on August 26, 1964 and required completion of abatement activities by December 15, 1964. In December 1964 the firm submitted a progress report indicating partial abatement had been achieved. In early 1966 the company requested a conference with the Health Department to discuss its progress in pollution abatement. By early 1967, the Company was reported to be working on plans for accomplishing abatement.

10. Borough of Highlands - Pollution abatement orders issued December 11, 1964 required the construction of necessary improved treatment facilities by April 1, 1965. In 1965 the Borough initiated studies to determine the feasibility of joining with Sea Bright and Rumson in a regional project, as well as the feasibility of connecting with the proposed Monmouth County Sewerage Authority. No decision has been made as to which regional approach will be selected.

11. Linden-Roselle Sewage District - Orders against this agency were issued January 22, 1963 requiring increased treatment by January 27, 1964. In January 1965 the Authority advised the Health Department that it was operating a pilot plant prior to construction of the necessary facilities for secondary treatment. By early 1967, pilot plant studies had been completed and an abatement timetable submitted.

12. Woodbridge Township (Sewaren) - Orders were issued on January 22, 1963 requiring increased treatment at this plant by January 27, 1964. An engineering study was completed on methods for providing increased treatment. The Township has also completed a study to determine the feasibility of connecting to the Middlesex County Sewerage Authority system as an alternate to upgrading existing treatment facilities.

13. Rahway Valley Sewerage Authority - Orders were issued January 22, 1963 requiring increased treatment by January 27, 1964. In September 1964 this agency advised the Health Department it was conducting pilot plant studies prior to the design of new treatment facilities. These studies are now underway, and an abatement timetable has been submitted.

14. Carteret - A consent judgment which will incorporate a time schedule for completion of activities, is being issued against the Borough of Carteret by the court. The Borough has undertaken a study to determine possible improvements in the collection system to reduce waste flow and the feasibility of joining the Rahway Valley Sewerage Authority as an alternate to upgrading existing facilities.

15. Joint Meeting - Engineering studies to achieve abatement were completed in late 1966.

Classification of the Raritan River and Raritan Bay in February 1966, has resulted in issuance of orders requiring submission of plans for secondary treatment for a number of communities and industries. The following list presents the polluters, the dates of orders, and the compliance date for submission of plans for upgrading to secondary treatment.

	Date Issued	Compliance Date
American Cyanamid Company (Bound Brook)	2-18-1966	6-1-1966
Johns Manville Products Corporation	2-18-1966	6-1-1966
Middlesex County Sewerage Authority	2-18-1966	6-1-1966
Borough of Manville	2-18-1966	6-1-1966
City of Perth Amboy	2-18-1966	6-1-1966
Borough of Sayreville	2-18-1966	6-1-1966
City of South Amboy	2-18-1966	6-1-1966
Woodbridge Township	2-18-1966	6-1-1966
Madison Township Sewerage Authority	4-7-1966	8-15-1966
Borough of Keyport	4-7-1966	8-15-1966
Borough of Keansburg	4-7-1966	8-15-1966
Borough of Atlantic Highlands.	4-7-1966	8-15-1966
Borough of Matawan	4-7-1966	8-15-1966
Matawan Twp. Mun. Ut. Authority (2 plants)	4-7-1966	8-15-1966

According to the Health Department, as of early 1967 virtually all of the above were making satisfactory progress, either in developing plans for upgrading existing facilities or in conducting studies to determine the feasibility of regional facilities.

New York City Department of Health

This agency has issued a number of orders against pollution. In many cases actual construction of pollution control facilities is being held in abeyance pending construction of municipal facilities by the City of New York. In early 1967 the status of orders issued by this agency was as follows:

1. Mount Loretto Home - Abatement orders issued March 27, 1962 were complied within April 1964.

2. St. Joseph's By-The-Sea - Abatement orders were issued March 27, 1962, against a system which is no longer in use. The sewage disposal facility of the new high school has been approved by the City Department of Health.

3. Richmond Memorial Hospital - Abatement orders were issued March 15, 1962. Compliance was obtained in September 1964, but due to poor operation the facility is presently not satisfactory.

4. Nassau Smelting - Abatement orders were issued on March 27, 1962. An extension has been granted until May 1969, the expected completion date of the Tottenville treatment plant. The necessary internal piping changes must be made prior to May 1969 so that immediate connection to the City sewer will be possible at that time.

5. Procter & Gamble - On April 5, 1963 this firm was ordered to abate pollution by April 1964. An extension has been granted until the Port Richmond West Branch interceptor is completed in June 1968. The necessary internal piping changes must be made prior to June 1968 to permit immediate connection to the City sewer at that time. Design work to accomplish this connection has been substantially complete.

6. S.S. White Company - Abatement orders were issued March 15, 1962. An extension has been granted until completion of the Oakwood Beach interceptor in April 1969. The necessary internal piping changes must be made prior to April 1969 to permit immediate connection to the City sewer at that time.

Interstate Sanitation Commission

This agency has one abatement order outstanding against the City of Elizabeth, requiring construction of interceptor sewers for two areas now discharging raw sewage to the Arthur Kill. Plans and specifications have been completed, and bids for this work are due April 11, 1967.

Plans and Construction of Municipal Plants

Through the combined efforts of state and interstate agencies responsible for pollution control in the area, a number of municipalities have undertaken necessary construction plans and studies to upgrade treatment levels, as follows:

1. **Keyport** - In 1962 this municipality completed a modernization and expansion program for its primary treatment plant at a cost of $361,000. It is now studying a regional approach rather than upgrade this plant to secondary.

2. **Keansburg** - In 1963 this municipality initiated a program of expansion for both its treatment plant and sewer system. Treatment plant additions were completed in 1964 to increase the plant design flow to 2.5 MGD at a cost of $190,000. The estimated cost for the completion of the sanitary sewer system was $160,000. The community is now investigating a regional facility in lieu of increased treatment.

3. **Madison Township (Laurence Harbor)** - In 1963 a new primary plant with a design flow of 1.0 MGD was placed in operation. Treated waste is discharged through an outfall 1700 feet into Raritan Bay. Design of secondary treatment facilities is underway.

4. **Atlantic Highlands** - In 1964 the municipality completed preliminary plans for a new secondary treatment plant. It then abandoned these plans and made a study of the feasibility of connecting to the proposed Monmouth County Sewerage Authority system. No decision has been made as to which approach will be taken.

5. **Port Richmond** - In 1964 New York City expended $973,900 for construction of a sludge storage tank and plant modifications. Plans for the West Branch interceptor have been completed and construction is scheduled for completion by June 1968. Eventually this plant will intercept and treat all wastes being discharged from Staten Island between the Narrows and Port Ivory. In addition, a completed study of the Bloomfield area indicated that this area should also be served by the Port Richmond plant. The East Branch interceptor is scheduled to be completed by December 1969. By December 1969, the plant

will be expanded to provide secondary treatment to 60 MGD with discharge to the Kill Van Kull. Estimated cost for this program is $40,981,000.

6. **Tottenville** - In 1964 the State of New York approved $103,000 for a comprehensive study for sewerage facilities for this area. By late 1966 this study had been completed. Present plans call for construction by May 1969 of a 6 mgd secondary plant with the necessary interceptor sewers, at an estimated cost of $4,631,000.

7. **Newtown Creek** - Construction of the Newtown Creek plant was completed in late 1966 at a cost of $48,800,000. Initial operation is scheduled for early 1967. This plant, which will provide secondary treatment for 310 MGD, will be a major step in reducing pollution in Upper Bay. Interceptor sewers to serve the eastern portion of Manhattan Island are scheduled for completion by September 1968. The total cost for this plant and necessary interceptor sewers is estimated at $165,240,000.

8. **Middlesex County** Sewerage Authority - In 1965 the Authority installed two new clari-flocculators which increased plant capacity from 52 to 78 MGD. The cost of this and other plant expansion programs was $1,093,100. The Authority has completed pilot plant studies and initiated design of secondary treatment facilities.

9. **Fresh Kills, Staten** Island - In 1965, the State of New York approved a study for this plant, now approximately 50 percent complete. This project will intercept and treat all wastes being discharged to the Arthur Kill from Staten Island from Fresh Kills south to the Outerbridge Crossing. Construction of a 10 MGD secondary plant and the necessary interceptor sewers is estimated to cost $11,677,000. Expected completion date is May 1971.

10. **Oakwood Beach** - Final design has been completed for the South Shore interceptor, now scheduled for completion of construction by April 1969. Following this and completion of plant expansion to 30 MGD, now scheduled for December 1970, all wastes from Staten Island between the Narrows and Princes Bay will receive secondary treatment prior to discharge. Estimated cost for this work is $29,578,000.

11. **Red Hook** - Preliminary plans were completed in 1965 for the East Branch interceptor. Selection of plant site and type of treatment are underway. This project will provide a secondary plant to treat 60 mgd of wastes now being discharged immediately north of the Narrows along the

Brooklyn shore. Total cost of this project is estimated at $44,309,000. Expected completion date for the plant and interceptor sewers is December 1970.

12. Highlands - In 1965, the borough abandoned its plans for a secondary treatment plant in order to investigate connection to the proposed Monmouth County Sewerage Authority. It has now abandoned this approach in favor of a connection to the Borough of Seabright.

13. Monmouth County - A study of the feasibility of a Monmouth County Sewerage Authority to serve the entire area of Monmouth County, N.J. has been completed and submitted to the New Jersey Health Department for review.

State and Interstate Programs

Prior to convening of the conference on pollution of Raritan Bay, the waters of the conference area had been classified by the Interstate Sanitation Commission and by the New York State Water Resources Commission. Their classifications are presented in the section of this report entitled "Pollution Abatement Needs."

In 1962 the Interstate Sanitation Commission issued a report on treatment requirements in the Arthur Kill. This report was based upon a study of the assimilative capacity of the Arthur Kill and established the following requirement for domestic and industrial waste discharges to these waters. "Domestic and Industrial waste plants must provide at least 75% reduction in the total pounds of BOD discharged per day or full secondary treatment with an 80% reduction in BOD, whichever produces the lower effluent BOD, as well as comply with all other standards."

In August 1964 the New Jersey State Department of Health issued regulations establishing a classification procedure for water within its jurisdiction. Effective April 15, 1965 classifications and criteria were adopted for the Raritan River and Raritan Bay below Fieldville Dam. In January 1966, the Department issued its proposed classifications for the Arthur Kill and its tributaries. Both of these classifications are presented in the section of this report entitled "Pollution Abatement Needs."

A number of other important activities were also accomplished during 1965. New York State declared that all discharges to waters within Interstate Sanitation Commission jurisdiction emanating from the State of New York must provide secondary treatment. The State of New Jersey also agreed to require secondary treatment on all discharges throughout the Interstate Sanitation Commission district. The Interstate Sanitation Commission issued a requirement for chlorination of all wastes discharged to the Upper Bay by the Summer of 1967. According to the Interstate Sanitation Commission most of the sources discharging to the Arthur Kill have agreed to meet the Commission's requirement for secondary treatment, and it is expected that such treatment will be provided by sources no later than the end of 1968.

In September 1965, new legislation was passed in the State of New York providing increased enforcement capability and authority to the New York State Health Department. In November 1965, voters in New York State approved a one billion dollar bond issue to make possible more rapid construction of needed waste treatment facilities throughout the State.

The impact of the discharge of raw or inadequately treated and disinfected wastes from the Upper Bay upon the waters of the study area has been discussed previously. In September of 1965, the Secretary of Health, Education, & Welfare called a conference on pollution of the Hudson River and its tributaries. The conferees included the New York and New Jersey State Health Departments, the Interstate Sanitation Commission, and the Department of Health, Education, & Welfare. Among the recommendations adopted by the Conferees and promulgated by the Secretary of Health, Education & Welfare following the conference, were the following:

"All discharge sources to the Hudson River and its tributaries, whether public, Federal installations, or industrial, shall receive a minimum of secondary treatment or its equivalent, and effective disinfection of the effluents as required to protect water uses.

"Industrial plants shall improve practices for the segregation and treatment of wastes to effect the maximum reduction of the following:

a. Acids and alkalis;
b. Oil and tarry substances;
c. Phenolic compounds and organic compounds that contribute to taste and odor problems;
d. Nutrient materials including ammonia, nitrogenous and phosphoric compounds;
e. Suspended material;
f. Toxic and highly colored wastes;
g. Oxygen requiring substances;
h. Heat;
i. Foam producing discharges;
j. Other wastes which detract from recreation uses, esthetic enjoyment or other beneficial uses of the waters.

"Surveillance and monitoring of the operation and maintenance of sewage and waste treatment facilities in the conference area shall be conducted by the States of New Jersey, New York, the Interstate Sanitation Commission, and the Department of Health, Education, and Welfare at locations and frequencies to yield reliable values of waste outputs and resulting receiving water quality, and to show their variations.

"The Federal conferee recommends the following time schedule for the foregoing program:

a. Designs for remedial facilities completed by January 1, 1967;
b. Financing arrangements completed by April 1, 1967;
c. Construction started by July 1, 1967;
d. Construction completed and plants placed into operation by January 1, 1970;
e. Commensurate schedules should be adopted for the interception and treatment of industrial wastes and wastes from Federal installations;
f. Existing schedules calling for earlier completion dates are to be met.

"The magnitude of the pollution problem caused by discharge from combined sewer overflows is recognized. The Department of Health, Education, and Welfare, in cooperation with the States of New Jersey, New York, and the Interstate Sanitation Commission, will undertake a review of the problem and develop a program for action for consideration by the Federal Government, the States and the Interstate Sanitation Commission by December 31, 1968."

Completion of the activities called for in the above recommendations will be of benefit to the waters of Raritan Bay by reducing the waste load entering the system through the Narrows.

POLLUTION ABATEMENT NEEDS

Classification and Water Quality Standards

Waters of the study area have been classified as to best usage by the agencies having authority to promulgate such classifications —— New York State Water Resources Commission, New Jersey State Department of Health, and Interstate Sanitation Commission. Each of these agencies, in adopting classifications for the various segments of water within the study area, have also promulgated applicable water quality standards based upon the assigned water usages. Table VI presents the existing classifications by these agencies, together with the highest assigned usage under classification. The study waters embrace a total of eight different classifications.

There is a need for a better definition of the assigned usages. The Interstate Sanitation Commission, operating under the provisions of the Tri-State Compact, has established two classifications. Class A is assigned to those waters expected to be used primarily for recreational purposes, shellfish culture, or the development of fish life. Class B waters are defined as those not expected to be used primarily for the same purposes. Such broad classification makes difficult the assignment of appropriate standards. Case in point: Bacterial standards for all Class A waters should be set for the highest permissable use —— shellfish propagation. In certain areas, however, optimum water use may be fish propagation or recreational use, both of which may require less stringent bacterial standards.

Water quality criteria promulgated by each agency for their classification assigned to these waters are contained in Volume III - Appendices.

Most of the criteria shown in Table VI are in general terms, with numerical values assigned only to a few parameters such as dissolved oxygen, pH and bacteria levels. Table VII compares the dissolved oxygen and bacterial criteria promulgated by each agency for various types of usage. There is a need for the regulatory agencies to agree on uniform criteria for identical classes of water quality. Although New York and New Jersey have identical bacterial standards for shellfish waters, the Interstate Sanitation Commission standard is based upon effluent quality rather than the quality of the shellfish water itself. New York and New Jersey standards do not indicate a bacterial criteria for bathing waters, however, the Interstate Sanitation Commission has a standard based upon effluent quality control.

Both New Jersey and the Interstate Sanitation Commission have similar dissolved oxygen requirements for shellfish and bathing waters —— not less than 50% of saturation; New York, however, calls for not less than 5 mg/l. With a chloride value of 12,500 mg/l and a water temperature of 25°C, both conditions of normal occurrence in the waters under study, 50% dissolved oxygen saturation corresponds to a concentration of only 3.7 mg/l, a figure significantly less than the 5 mg/l required by New York. In

TABLE VI

EXISTING CLASSIFICATIONS OF STUDY WATERS

Water Area	Agency & Classification New York Water Resources Commission	 New Jersey State Dept. of Health	 Interstate Sanitation Commission	Highest Assigned Usage under Classification
Arthur Kill - Outerbridge Crossing to Newark Bay	II	TW-3	B	Non-Recreation & Navigation
Arthur Kill - Outerbridge Crossing to Tottenville	I	TW-3	A	Shellfish (ISC) Recreation (ISC) Fishing (N.Y.)
Raritan Bay	SB	TW-1	A	Shellfish (ISC & NJ) Bathing (NY & NJ)
Raritan Bay Shellfish Area	SA	TW-1	A	Shellfish (ISC,NY,NJ)
Lower Bay	SB	-	A	Shellfish (ISC) Bathing (NY)
Sandy Hook Bay	-	TW-1	A	Shellfish & Bathing (NJ, ISC)
Raritan River, from Fieldville Dam to Raritan Bay	-	TW-1	-	Shellfish & Bathing (NJ)

TABLE VII

COMPARISON OF WATER QUALITY CRITERIA

Agency & Class		Criteria for	
		Dissolved Oxygen	Coliform Bacteria
		Shell Fishing for Market Purposes	
NY	SA	NLT* 5.0 mg/l	Median MPN not over 70/100 ml
NJ	TW-1	NLT 50% of Saturation	Median MPN not over 70/100 ml
ISC	A	NLT 50% " "	Effluent NGT** 1/ml in more than 50%
		Bathing	
NY	SB	NLT 5.0 mg/l	No criteria
NJ	TW-1	NLT 50% Saturation	No criteria
ISC	A	NLT 50% Saturation	Effluent
		Fishing	
NY	I	Ave. NLT 50% any week NLT 3.0 mg/l anytime	Effluent disinfection if required by ISC
NJ	-		
ISC	-		
		Non-Recreational Use	
NY	II	Ave. of NLT 30% saturation any wk. of year	-
NJ	TW-3	NLT 30% saturation or 3 mg/l whichever is less	-
ISC	B	NLT 30% saturation	-

*NLT = Not less than
**NGT = No greater than

their criteria for non-recreational waters both New York and the Interstate Sanitation Commission require not less than 30% dissolved oxygen saturation. New Jersey, on the other hand, has a dissolved oxygen requirement of not less than 30% saturation or 3 mg/l, whichever is less. Again, under the same conditions of temperature and chloride noted previously, 30% saturation of dissolved oxygen could present levels as low as 2.2 mg/l in the water.

In addition to the need for uniform classifications and water quality criteria, there is a need for more specific definitions of such terms as medium, average and sampling frequency.

Proposed Water Quality Requirements

Tables VIII through X present recommended water quality requirements to be applied to the Arthur Kill, Raritan Bay, and Raritan River. These requirements are recommended as indicating water quality suitable for the highest assigned usage by the three agencies which have classified these waters.

Requirements for the Arthur Kill are such as to permit utilization of this water for pleasure boating, commercial navigation and survival of aquatic life. In addition, criteria were selected so as to minimize the effect of the Arthur Kill upon the adjoining waters of Raritan Bay.

Requirements for Raritan Bay and Raritan River include two bacteriological limits, applicable to either shellfish areas or to water contact recreational areas. Since the majority of water contact recreation is in the form of bathing along the shoreline, higher limits have been set to allow for a reasonable amount of soil runoff from the shore. The commercial shellfishing areas, on the other hand, are removed from such runoff influences and the more stringent bacterial requirements can be maintained if pollution is controlled.

TABLE VIII

WATER QUALITY REQUIREMENTS

ARTHUR KILL

Location - Arthur Kill from Outerbridge Crossing north to Port Ivory.

Water Use - Pleasure boating, commercial navigation, industrial cooling water, wastewater assimilation.

Coliform Bacteria - Number/100 ml

Maximum Value 5,000 except during periods of stormwater runoff.

Fecal Coliform - Number/100 ml

Maximum value 500 except during periods of stormwater runoff.

Turbidity

No turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of the water.

Odor

No obnoxious odors of other than that of natural origin.

Temperature °F

Single daily value or average not more than 90°.

Oil

Substantially free from visible floating oil.

Floating Solids and Debris

Substantially free of floating solids and debris from other than natural sources.

Bottom Deposits

Substantially free of sludge banks and oil deposits.

TABLE VIII

WATER QUALITY REQUIREMENTS

ARTHUR KILL

Dissolved Oxygen - mg/l

Average (May through September) not less than 4.0

Single daily value or average not less than 2.5

Phenolic-Type Compounds - mg/l

Single daily value or average not more than 0.02

Toxic Substances

None in such concentrations as to render the water unsuitable for the assigned uses.

TABLE IX

WATER QUALITY REQUIREMENTS

RARITAN BAY AND RARITAN RIVER

Location - All areas of Raritan, Lower, and Sandy Hook Bays not used for commercial shellfish propagation; Raritan River from Raritan Bay to Fieldville Dam; tidal portions of tributaries to these waters unless classified separately.

Water Use - Recreational bathing & boating, propagation of commercial and sport finfish.

Bacteria - Number/100 ml

(a) Number of bacteria shall be the arithmetic average of the last five consecutive sample results.

(b) Satisfactory area if coliform are less than 1,000 and Fecal Coliform less than 200.

(c) Single sample results of over 5,000 coliforms shall require immediate investigation as to cause. Items to be considered in the judgment of cause and action to be taken include the sanitary survey, winds, currents and weather conditions.

(d) The above notwithstanding, isolation of any known pathogenic bacteria shall render the area unsatisfactory.

Turbidity

No turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of water.

Odor

No obnoxious odor of other than natural origin.

Temperature - °F

Not more than 85°.

Oil

Substantially free of visible floating oil.

TABLE IX

WATER QUALITY REQUIREMENTS

RARITAN BAY AND RARITAN RIVER

Floating Solids and Debris

Substantially free of floating solids and debris from other than natural sources.

Bottom Deposits

Substantially free of muck and debris of other than natural origin.

Dissolved Oxygen - mg/l

Annual Average:	Not less than 5.0
Single Value:	Not less than 4.0

Phenolic-Type Compounds - mg/l

Not more than 0.005

Miscellaneous Trace Contaminants and Radionuclides

Shall not be present in such concentrations as to render the water unsuitable for the assigned uses.

TABLE X

WATER QUALITY REQUIREMENTS

RARITAN BAY SHELLFISH AREAS

Location - Those areas of Raritan, Lower and Sandy Hook Bays used for commercial shellfishing.

Water Use - Commercial Shellfish

Bacteria - Number/100 ml

Maximum value 70

Other Parameters

Criteria for all parameters other than bacteria shall be as indicated in Table IX, Requirements for Raritan Bay and Raritan River.

Treatment and Surveillance

In certain cases, the present waste loads imposed upon the study area waters exceeds the available assimilative capacity. Improved treatment —— secondary being a required minimum —— is needed to reduce the quantity of oxygen demanding wastes now being discharged by both industries and municipalities. Control of the present bacteriological contamination at bathing beaches and shellfish waters requires a program of year-round effective disinfection of all sewage now being discharged to the study waters and to adjacent waters as far north as those around Manhattan Island in Upper Bay.

The present sewered population discharging directly to the study waters is estimated at 1.25 million persons. With the contemplated growth rate of the area, the sewered population is expected to increase ultimately to 3.6 million. This increase in tributary population accentuates the need for a minimum of secondary treatment of all wastes. When the sewered population approaches the ultimate secondary treatment may not be sufficient, therefore, advanced waste treatment processes may be required to protect these waters. Such advanced processes, commonly referred to as tertiary treatment, have yet to be applied on such a large-scale basis, however, development of these techniques is proceeding in such a fashion that adequate treatment methods will be available when needed. It is important to note that the effectiveness of increased treatment measures will be reduced if municipalities and industries do not provide qualified operators and sufficient funds for maintenance and operation.

Agencies having jurisdiction should reallocate their priorities for State and Federal construction grants and similar assistance to those areas affecting water quality in Raritan Bay in order to insure prompt construction of needed new plants and the upgrading of existing facilities. Particular emphasis should be placed on support of the necessary public expenditures for upgrading treatment. Once construction has been completed those agencies having jurisdiction should undertake more rapid enforcement of existing rules and regulations relating to water pollution control, including programs aimed at insuring compliance by adequate surveillance and inspection activities.

Due to contamination in localized areas such as marinas and docks, regulations should be adopted requiring adequate treatment facilities on all recreational and commercial vessels utilizing these waters. In the event holding tanks are utilized by such vessels adequate shore facilities must be required to handle wastes from these sources and proper regulations developed to insure use of such facilities.

Until such time as the above actions have been taken and decreases noted in the present bacterial contamination, the responsible authorities should undertake such measures as are necessary to reduce hazards to the health of persons utilizing these waters. The existing restrictions on harvesting of shellfish for commercial purposes should be continued until such time as improvement in water quality has been sufficient to warrant their reopening. The use of the waters by the public for water contact recreation, such as bathing, should be similarly restricted to those areas free of contamination.

Proposals such as the barrier at the mouth of the Narrows should be evaluated by water pollution control agencies, not as an alternate to, but as an additional measure for protection for these waters.

Additional removal of industrial waste contaminants will be required to permit restoration of the waters of the Arthur Kill to levels suitable for propagation of aquatic life and for non-contact water based recreation. The specific assignment of permissable waste loadings should be made by the responsible agencies having jurisdiction, utilizing as guidelines studies conducted by the Interstate Sanitation Commission of available assimilative capacity in the Arthur Kill and the criteria presented in Table VIII. Such assignment of permissible waste loadings should consider increases in loads anticipated as a result of future growth of both municipal and industrial developments utilizing the Kill as a receiving stream.

ANALYTICAL RESULTS

General

The following results of chemical, bacteriological and biological studies in the waters of the Project study area are based upon a variety of sampling programs. In Raritan Bay and Arthur Kill the Project conducted an intensive sampling operation, with weekly sampling at each station during the 13-month period from August 1962 through September 1963. From September 1963 to May 1966 the Project conducted a surveillance program which involved collecting of monthly samples at selected stations in the Bay and Kill.

The intensive sampling program was designed to permit mathematical analyses of the variations noted in parameter values. The results of such analyses are presented in detail in the section of this report entitled "Special Studies." The surveillance operation was pursued so as to maintain updated water quality data and to provide information on any changes which might have occurred during the period of surveillance. The sampling stations used by the Project in Raritan Bay and Arthur Kill are presented in Figure 3.

Analytical data presented on the Raritan River are based upon samples collected by the Project as well as data supplied by the Middlesex County Sewerage Authority. The sampling stations utilized on the Raritan River are shown in Figure 4.

Discussion of results has been divided into the three major bodies of water studied —— Raritan Bay, Arthur Kill and Raritan River. Where statistically significant, the predominant cycles affecting parameter variations, as determined by the mathematical analyses, have been included.

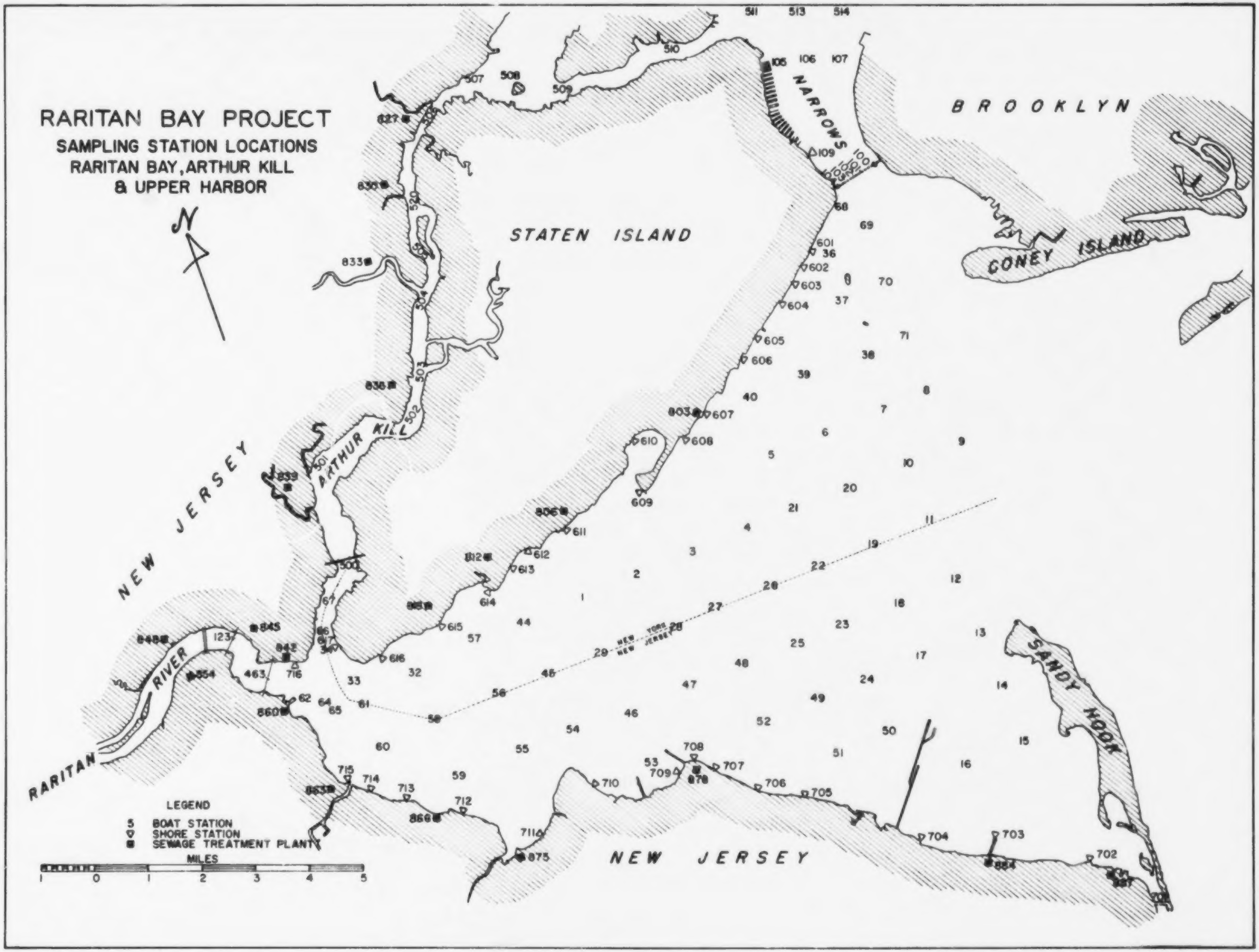
RARITAN BAY PROJECT
SAMPLING STATION LOCATIONS
RARITAN BAY, ARTHUR KILL
& UPPER HARBOR
N
STATEN ISLAND
BROOKLYN
CONEY ISLAND
NARROWS
SANDY HOOK
NEW JERSEY
NEW JERSEY
ARTHUR KILL
RARITAN RIVER
NEW YORK
NEW JERSEY
LEGEND
5 BOAT STATION
▽ SHORE STATION
■ SEWAGE TREATMENT PLANT
MILES
1 0 1 2 3 4 5
511
513
514
510
105
106
107
507
508
509
827
109
100
830
68
69
833
601
36
602
603
70
37
604
71
605
606
38
836
39
8
40
803
607
7
6
610
608
9
5
10
839
20
609
806
21
611
4
11
19
3
812
612
2
613
22
12
500
26
614
1
18
27
44
816
615
28
23
13
845
123
848
29
17
843
616
32
57
25
48
716
45
24
463
854
33
47
14
49
62
64
56
61
860
65
46
52
58
54
50
15
60
55
708
53
707
51
709
16
878
710
706
705
715
714
713
59
712
863
866
704
703
711
875
884
702
887
502
503
504

FIGURE 3

GPO 956-592

SAMPLING STATION LOCATIONS
RARITAN RIVER

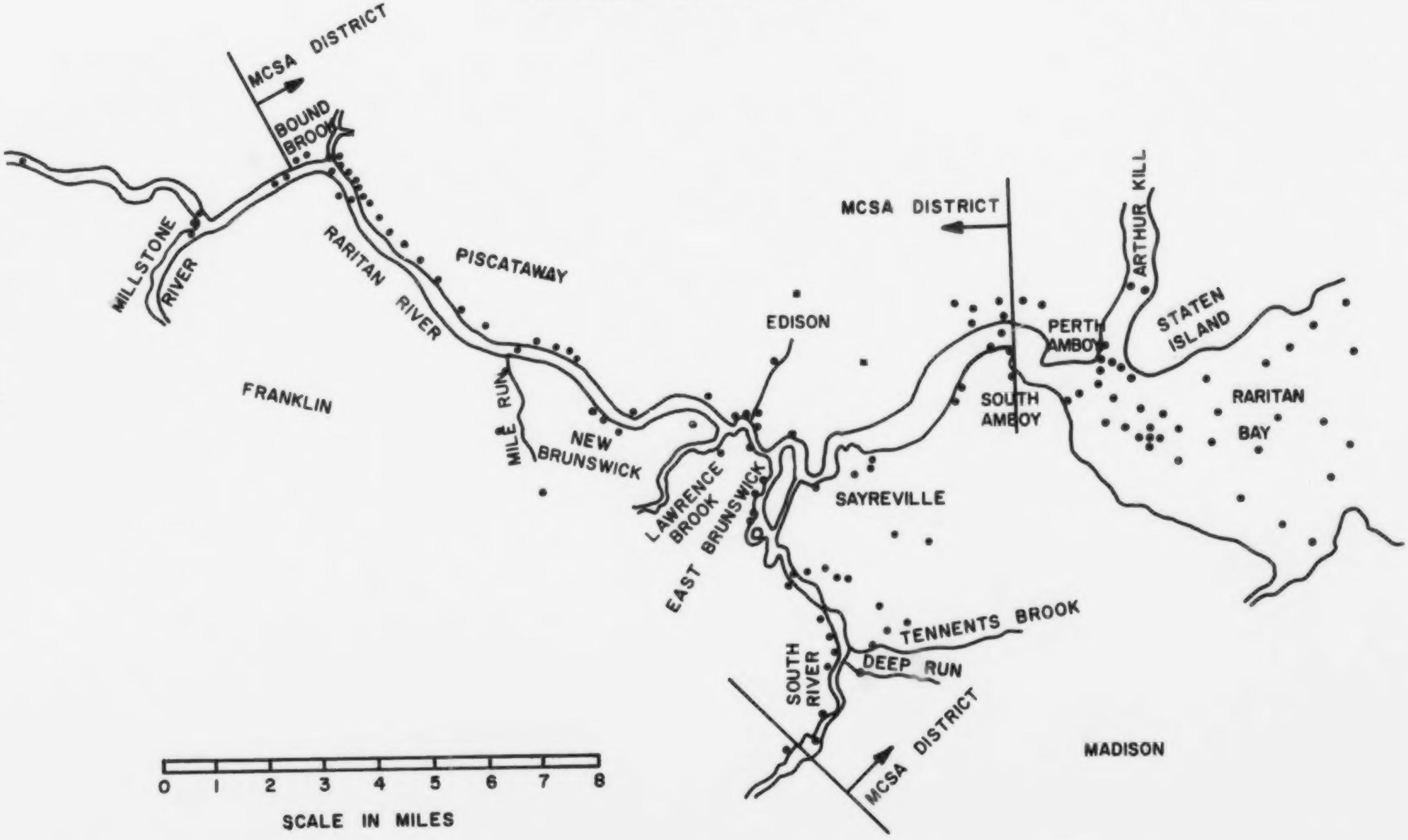
MCSA DISTRICT
BOUND BROOK
MILLSTONE RIVER
RARITAN RIVER
PISCATAWAY
FRANKLIN
MILE RUN
NEW BRUNSWICK
LAWRENCE BROOK
EAST BRUNSWICK
EDISON
SAYREVILLE
MCSA DISTRICT
SOUTH AMBOY
PERTH AMBOY
ARTHUR KILL
STATEN ISLAND
RARITAN BAY
TENNENTS BROOK
DEEP RUN
SOUTH RIVER
MCSA DISTRICT
MADISON
0
1
2
3
4
5
6
7
8
SCALE IN MILES

FIGURE 4

GPO 956-592

Raritan Bay

Water Temperature

Mean water temperatures were found to be uniform throughout with a range of from 15 to 16°C. For 44 stations mathematical analyses indicated an expected range of water temperature from -1.3 to 26.1°C, and with a mean value of 12.4°C. The major variation in water temperature was found to be due to an annual seasonal cycle.

Chloride

Chloride concentrations were uniform throughout, ranging from 13,000 to 14,000 mg/l. The predominant component affecting chloride concentrations, which could be explained by mathematical analyses, was an annual variation.

BOD_5

Observed BOD values ranged from an average of 3 to 4 mg/l in the western end of the Bay to values of less than 2 mg/l at the ocean extremity. The highest BOD value observed was 11 mg/l at Station 56. During the surveillance operation, a maximum of 12.0 mg/l was found at Station 27.

Dissolved Oxygen

Average dissolved oxygen concentrations, as shown in Figure 5, ranged from 6 mg/l at the mouth of the Arthur Kill to values of 9 mg/l in the center of the Bay along a band reaching from Princess Bay, Staten Island, to Sandy Hook Bay. East and north of this band average dissolved oxygen levels decreased to 6 mg/l. The highest average dissolved oxygen level —— 10 mg/l —— was found in Sandy Hook Bay. Minimum dissolved oxygen values recorded were approximately 2 mg/l at all stations except 34, where levels as low as 1.4 mg/l were observed.

Variation in dissolved oxygen throughout the Bay was attributed to a predominant annual variation with secondary effects caused by tidal and diurnal cycles. During the winter, values throughout the Bay were 9 to 10 mg/l with virtually no dissolved oxygen gradient. During the spring months dissolved oxygen values remained 9 to 10 mg/l but concentration gradients began to appear, with lower concentrations near the Narrows and near the confluence of the Raritan River and Arthur Kill. In the summer gradients were more pronounced, with dissolved oxygen values ranging from 10 mg/l in the center of the Bay to 4 mg/l in the vicinity of the Narrows, Raritan River and Arthur Kill. During autumn the gradient essentially disappeared and dissolved oxygen concentrations throughout the Bay were on the order of 5 to 7 mg/l. From a dissolved oxygen standpoint, autumn appears to be the most critical period throughout the Bay, although near the Narrows and the junction of the Raritan River and Arthur Kill, equally critical dissolved oxygen values were found during the summer.

Photosynthetic production of oxygen by aquatic life appeared to be a major factor in maintaining Bay dissolved oxygen levels. Biological surveys showed that an increase in netplankton concentration was accompanied by an increase in dissolved oxygen levels. Increases in the zooplankton population, on the other hand, were accompanied by decreasing dissolved oxygen levels with a simultaneous occurrence of lowest dissolved oxygen concentrations and peak zooplankton populations. Respiration of the dominant zooplankters found during peak populations could utilize as much as 27 mg/l per day of oxygen, according to previous studies.* This large loss of oxygen due to respiration was offset, at least partially, by simultaneous blooms of nanoplankton which are active oxygen producers.

Special studies were conducted at two stations in Raritan Bay to determine the net effect of photosynthetic production and respiration by marine organisms. The results, presented in Figure 6, suggest that oxygen production in the Bay is essentially limited to the top 11 feet, with peak production occurring in the upper six feet. Between 38 and 55% of the oxygen produced by photosynthesis was consumed by respiration, with the remainder being made available to the waters of the Bay.

Dissolved oxygen mean concentrations found during surveillance studies were about 1 mg/l lower in the western end of the Bay than those observed during the intensive study. Other areas of the estuary remained unchanged.

Phenol

Limited analyses for phenolic-type compounds indicated maximum values of phenol of 8 to 12 ppb at both the easterly and westerly extremities of the Bay. At the easterly end phenol values were highest near the Narrows and decreased uniformly on a line towards Sandy Hook Bay.

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*Conover 1959

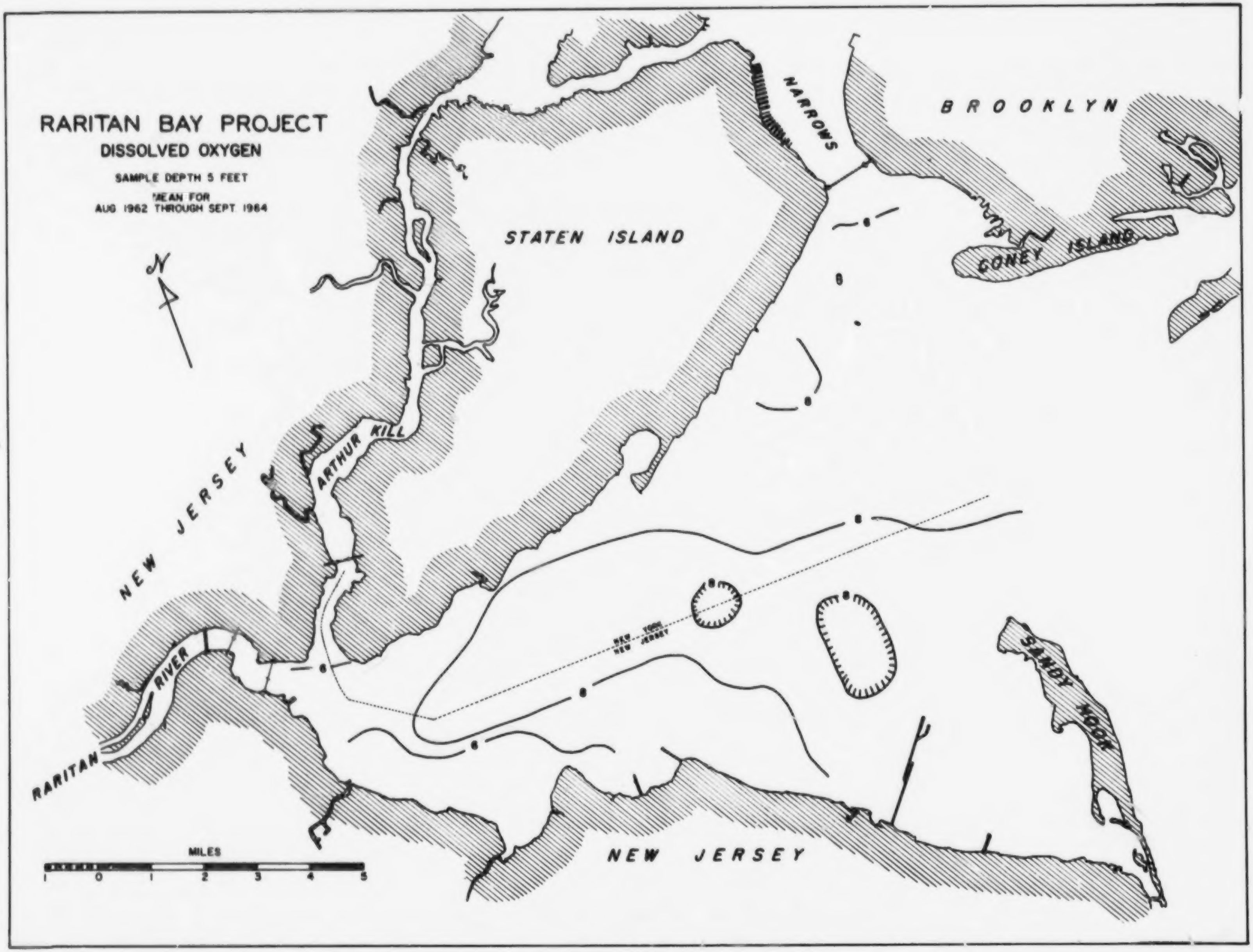
RARITAN BAY PROJECT
DISSOLVED OXYGEN
SAMPLE DEPTH 5 FEET
MEAN FOR
AUG 1962 THROUGH SEPT 1964
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN
RIVER
NEW YORK
NEW JERSEY
SANDY HOOK
NEW JERSEY
6
6
6
6
6
6
6
6
MILES
1
0
1
2
3
4
5

FIGURE 5

GPO 956-592

5x

OXYGEN PRODUCTION, UPTAKE & YIELD

PHOTOSYNTHETIC ZONE

RARITAN BAY

AUGUST 1964

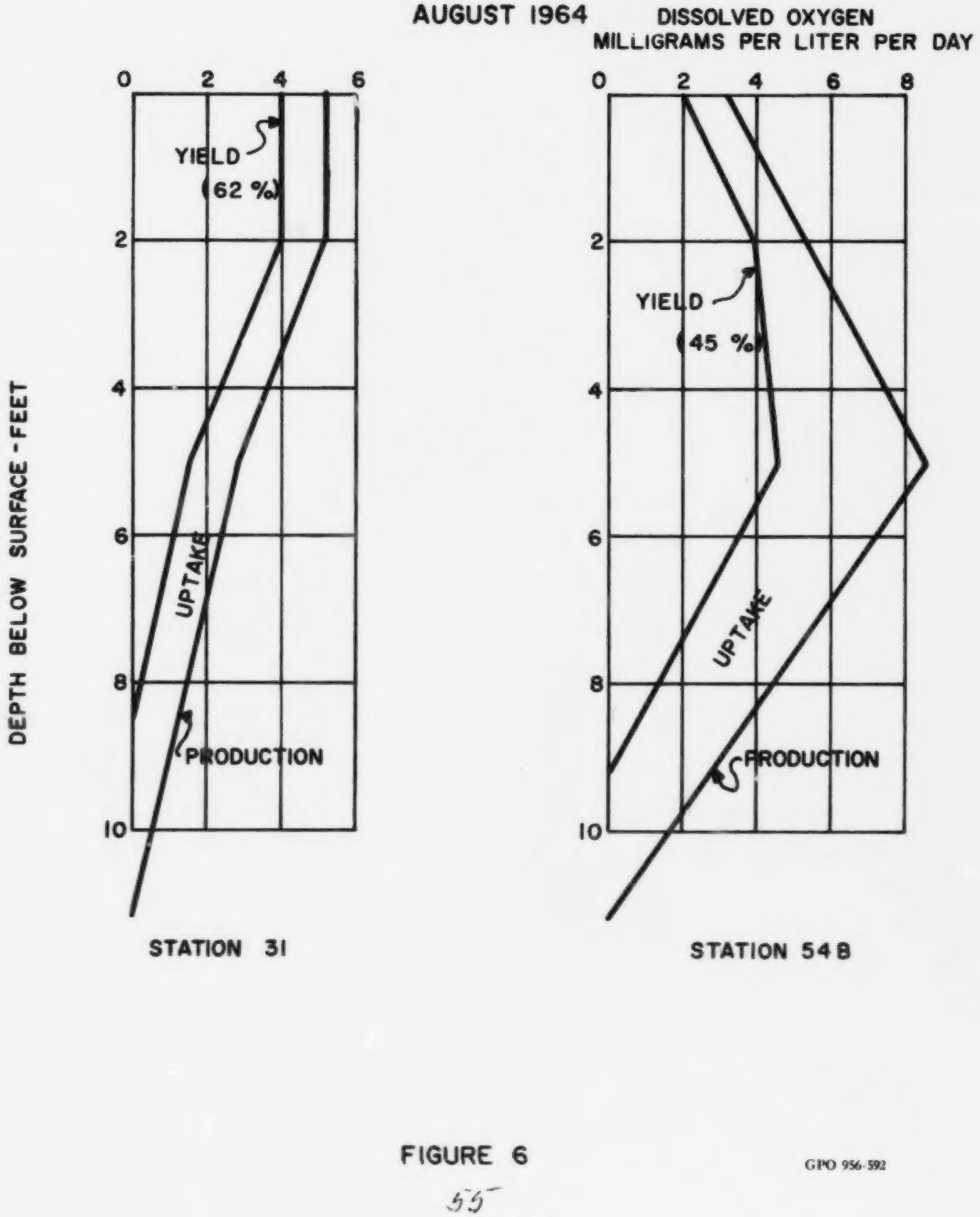

FIGURE 6

GPO 956-592

55

Bacteriological Density

Analyses were performed for total coliform and fecal coliform by both MPN and MF procedures and for fecal streptococcus by MF procedures. Figure 7 presents the mean MPN confirmed coliform counts for the Bay. High densities were found both in the vicinity of the Narrows and at the junction of the Arthur Kill and Raritan River. From these two sources coliforms appeared to radiate out into the Bay. Those stations with the lowest mean counts form an apparent edge between the two radiating sources appearing as a straight band running from Princess Bay, Staten Island, to Sandy Hook Bay. Geometric mean counts for MPN confirmed coliform ranged from 10,000 per 100 ml at the Narrows, and 7,000 per 100 ml at the mouth of the Raritan River to less than 50 per 100 ml in Sandy Hook Bay.

Figure 8 presents the bacteriological counts found along a profile following the New York-New Jersey state line through the Bay. For each of the indicator organisms, high counts were observed at both extremities of the profile with a reduction of counts near the center. A similar profile extending from the Narrows to Sandy Hook, as shown in Figure 9, indicates a high bacteriological density in the vicinity of the Narrows with a decline proceeding south to Sandy Hook Bay.

Results of bacteriological sampling on the Staten Island shoreline are presented in Figure 10. Figure 11 presents similar results for the New Jersey shoreline of Raritan Bay.

The Staten Island shoreline shows gross contamination by coliform bacteria. MPN confirmed coliform counts greater than 2,400 per 100 ml were found at all stations but 607 and 609. The geometric mean MPN coliform densities on the shoreline ranged from 100 to more than 2,400 per 100 ml. Highest counts were noted at either end of the profile, indicating a greater contamination in the vicinity of the Narrows and in the area of the confluence of the Arthur Kill and Raritan River. Both fecal coliform and fecal streptococcus exhibited the same general pattern as total coliform. The high fecal coliform density and the ratio of fecal streptococcus group organisms, which are characteristic of human feces, strongly suggests that this contamination results from human sources.

Bacteriological counts along the New Jersey shoreline were lower than those along Staten Island although MPN coliform counts in excess of 2,400 per 100 ml were obtained at most stations. Maximal counts were found at the westerly end of the shore near the junction of the Raritan River and Arthur Kill, with a decrease noted proceeding easterly towards Sandy Hook. A secondary peak was noted in the vicinity of Station 702 at the mouth of the Navesink and Shrewsbury Rivers. As on the Staten Island shoreline, the relative magnitude of the various indicator organisms strongly suggests that this contamination is attributed to the discharge of human wastes.

Mathmatical analyses of the observed variations in bacteriological densities in the Bay waters indicated that the most predominant component which could be explained was a seasonal cycle. Similar results were obtained for both the Staten Island and New Jersey shore stations as well as for the effluents from municipal sewage treatment plants.

This seasonal effect on bacteriological densities appeared to be related to variations in water temperature, probably due to temperature effects upon survival of the various organisms. During winter, lower counts were observed throughout the Bay, although high counts were still found near the Narrows and junction of the Raritan River and Arthur Kill. With the advent of spring and warmer water temperatures, high bacteriological counts radiated outwards from these two source areas. During the summer and autumn the pattern closely resembled that shown in Figure 8 for the yearly mean, except that slightly lower counts were observed during the summer at the western end of the Bay. Bacteriological counts in the Narrows were found to be lowest during the spring and to reach a maximum in the summer. At the western end of the Bay the reverse was true. At the mouth of the Raritan River maximum counts were found during the winter with minimal counts during the summer season.

No significant changes in the above bacteriological pattern or in the observed range of values were noted during the period of surveillance.

Plankton and Nutrients

Plankton analyses were carried out at the eight sampling stations shown in Figure 12. Three of these stations, 463, 54B, and 18, were chosen as most representative of the wide environmental differences within the estuary. Station 463 represents the influence of the Raritan River and had the widest range of salinity. Station 54B is located in the path of outgoing water movement, as shown by Project dye studies, and hence would be readily affected by pollution sources in the western end of the Bay. Station 18 near Sandy Hook is furthest removed from known pollution sources, and it is where the more oceanic waters enter Raritan Bay.*

The seasonal variation and abundance of phytoplankton at these three stations is shown in Figure 13. With one exception, total cell numbers exceeded 10,000 per ml; highest cell densities occurred during July and August. The greatest phytoplankton density was found at Station 54B.

During the period of study nanoplankton comprised 94% or more of the total phytoplankton population. At all stations the nanoplankton population was high during the summer and low in the winter. (Nanoplankton blooms developed as water temperatures increased sharply in May and June and showed peak densities coincident with peak water temperatures.) During summer blooms nanoplankton comprised as much as 99.9% of the total plankton population.

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*Jeffries 1962

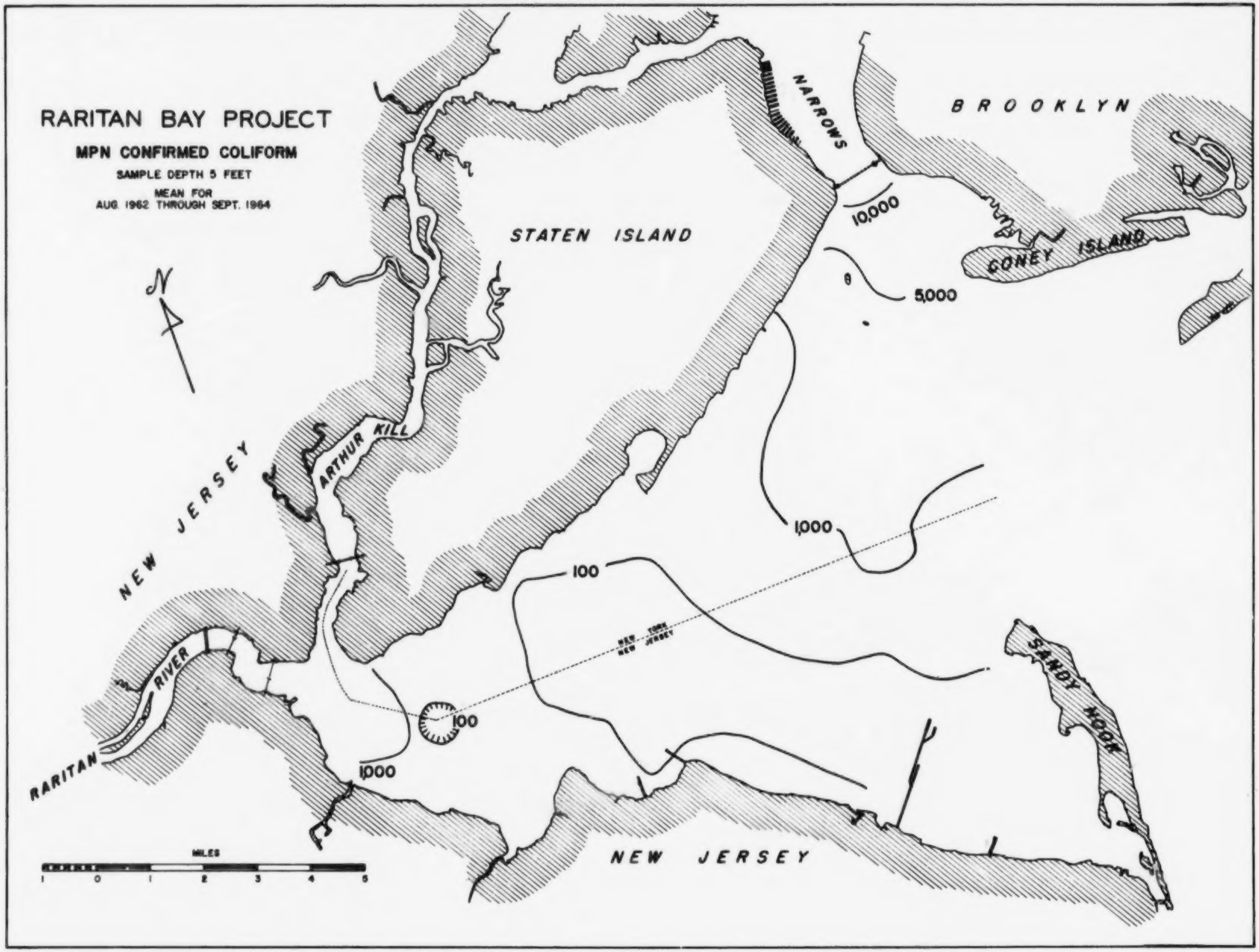

RARITAN BAY PROJECT
MPN CONFIRMED COLIFORM
SAMPLE DEPTH 5 FEET
MEAN FOR
AUG. 1962 THROUGH SEPT. 1964
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
10,000
5,000
1,000
100
NEW YORK
NEW JERSEY
100
1000
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 7

GPO 956-592

RARITAN BAY PROJECT
BACTERIAL PROFILES
N. Y.-N. J. STATE LINE

SAMPLE DEPTH 5 FEET

MEAN FOR
AUG. 1962 THROUGH SEPT. 1964

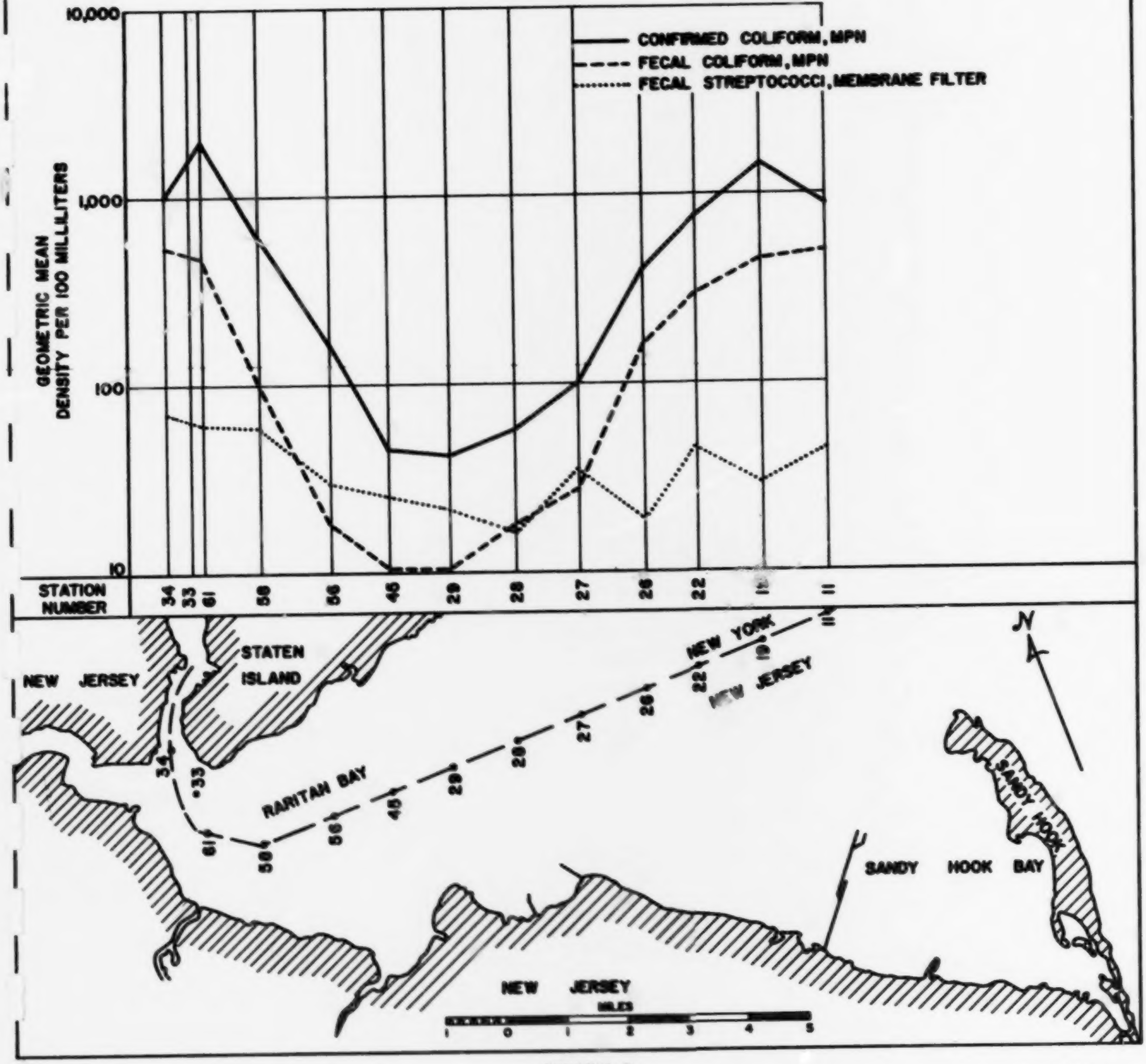


FIGURE 8

59

RARITAN BAY PROJECT
BACTERIAL PROFILES
EASTERN EXTREME OF BAY

SAMPLE DEPTH 5 FEET

MEAN FOR
AUG. 1962 THROUGH SEPT. 1964

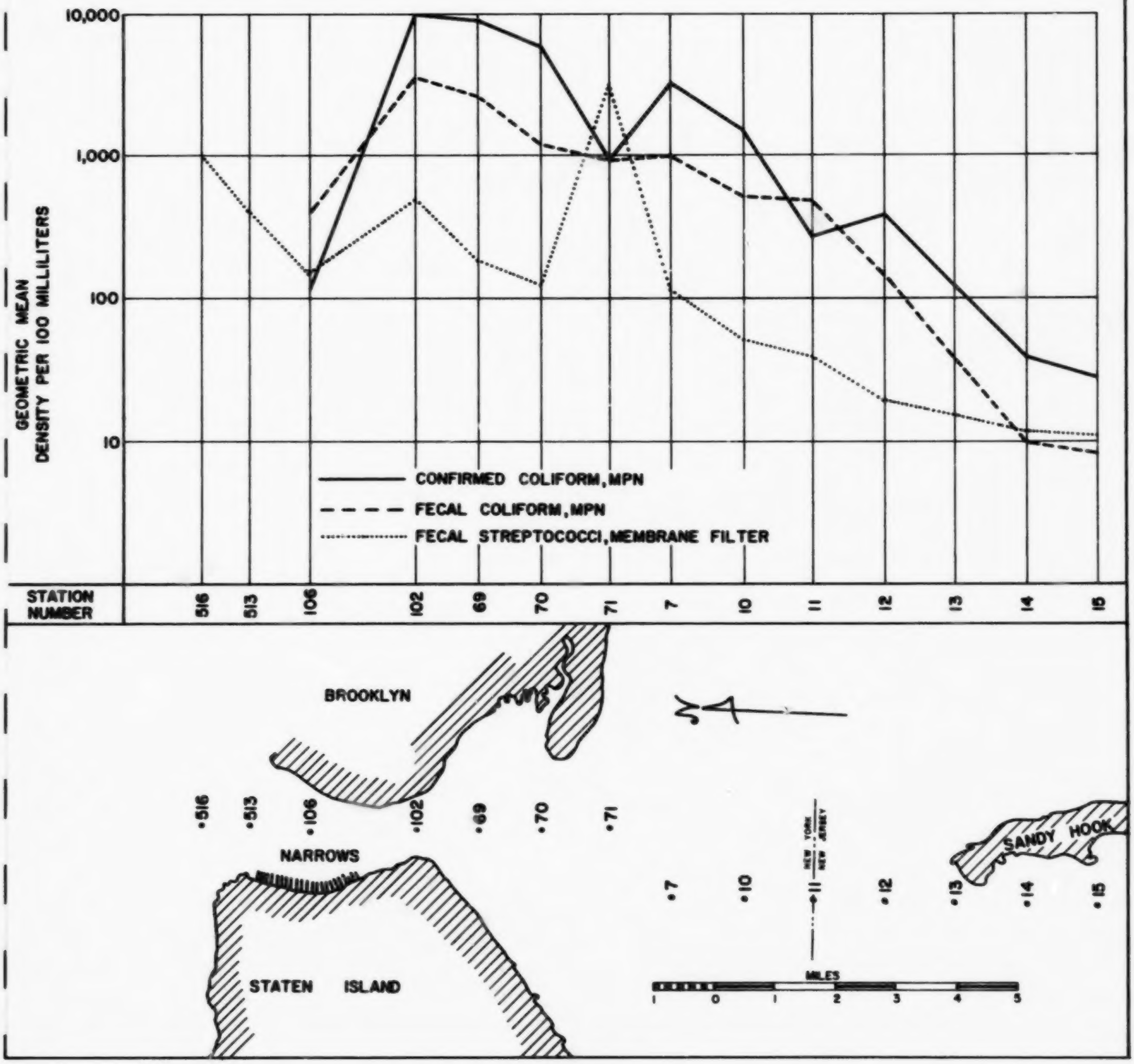


FIGURE 9

GPO 956-592

RARITAN BAY PROJECT
BACTERIAL PROFILES
STATEN ISLAND SHORE

SAMPLE DEPTH 5 FEET

AUG. 1962 THROUGH SEPT. 1964

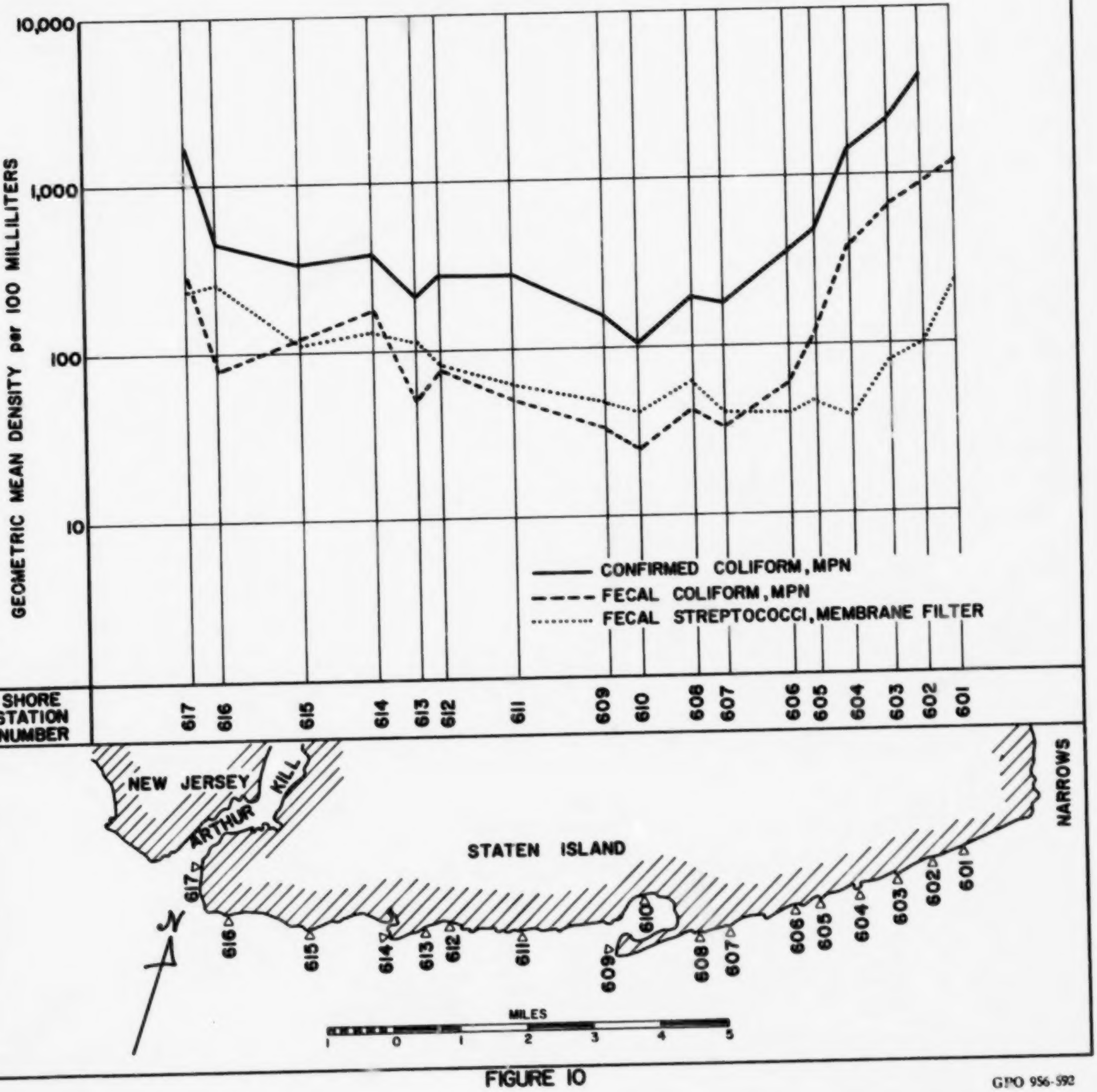


FIGURE 10

GPO 956-592

RARITAN BAY PROJECT
BACTERIAL PROFILES
NEW JERSEY SHORE

SAMPLE DEPTH 5 FEET

AUG. 1962 THROUGH SEPT. 1964

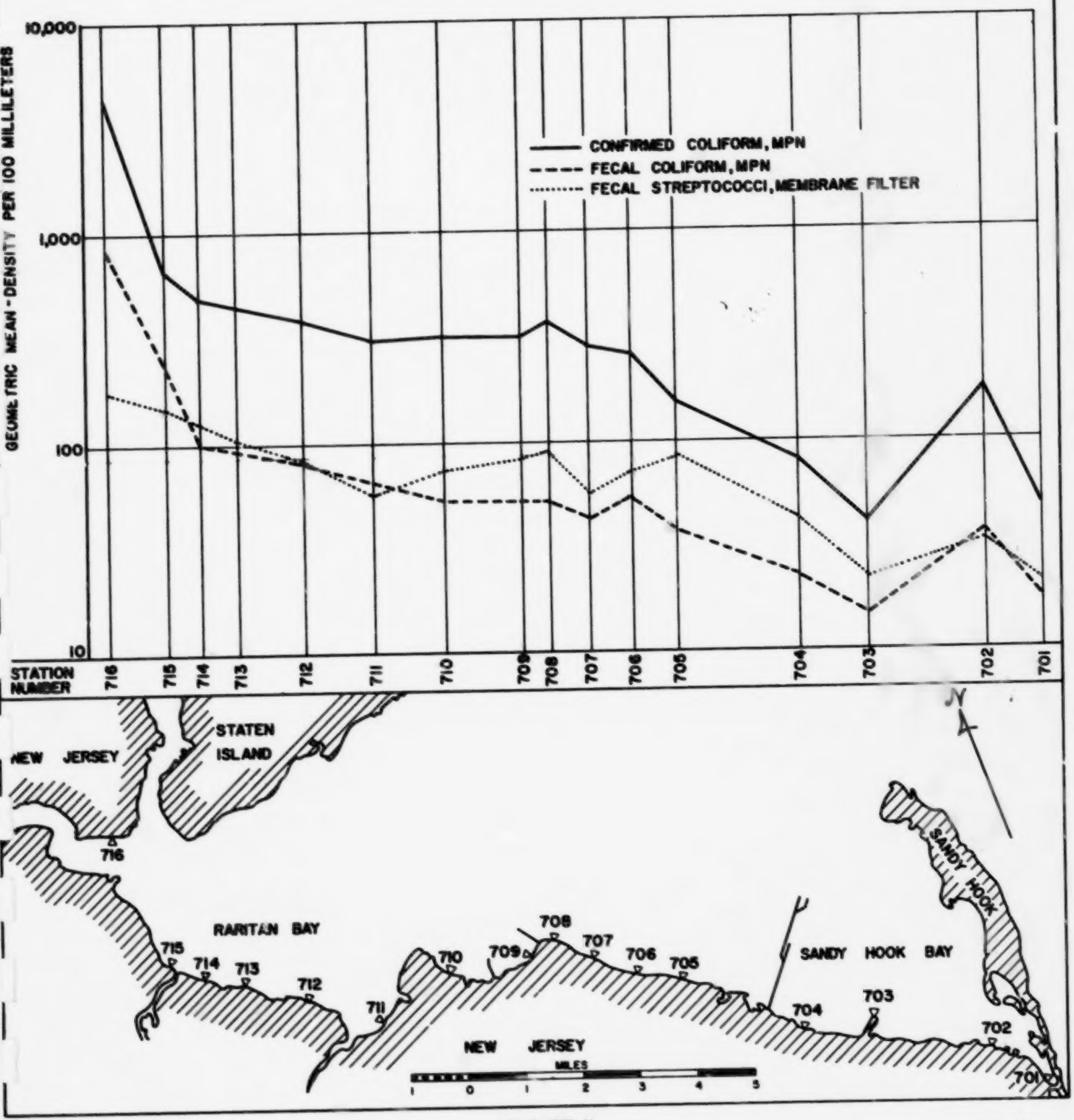
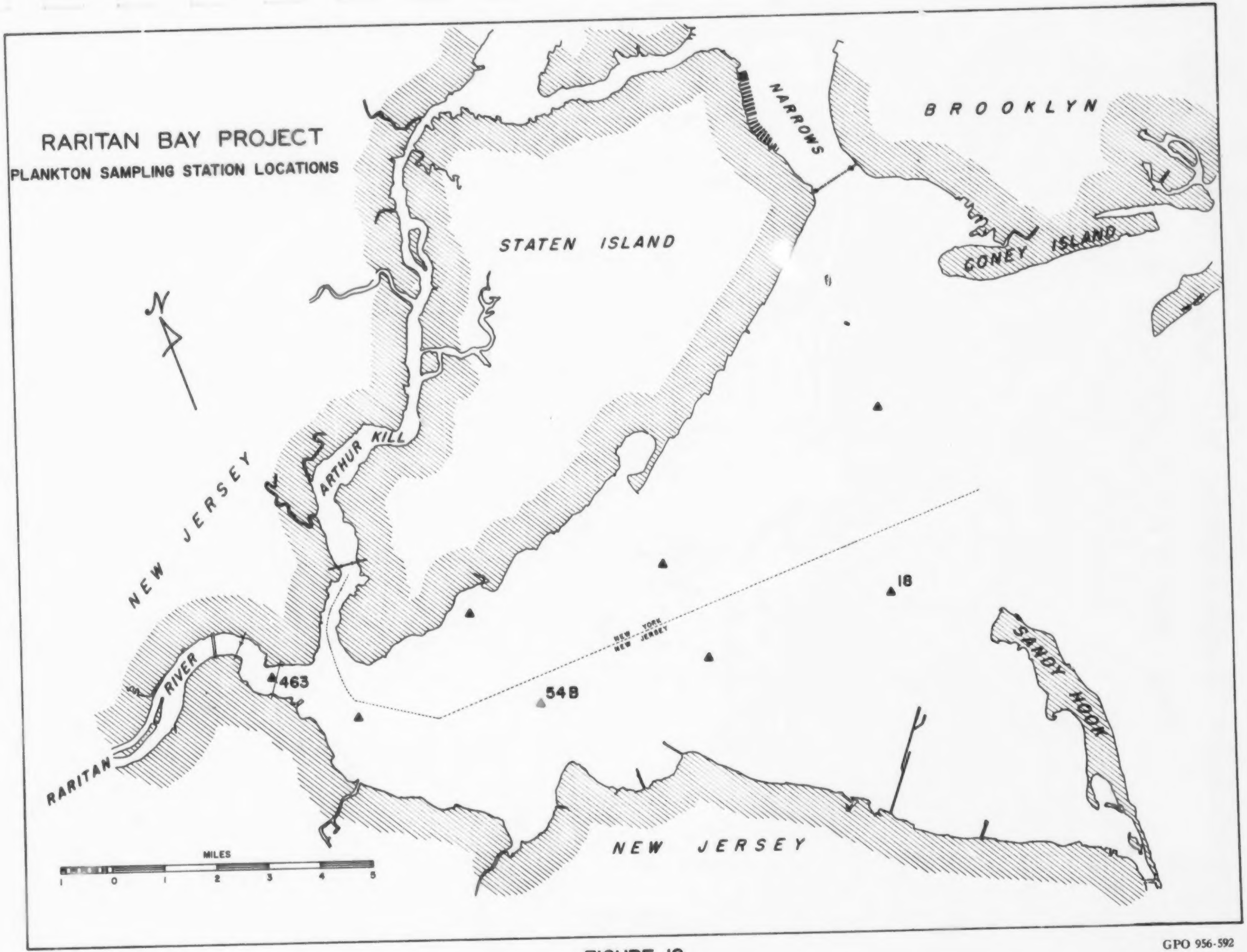


FIGURE 11



RARITAN BAY PROJECT
PLANKTON SAMPLING STATION LOCATIONS

BROOKLYN
NARROWS
CONEY ISLAND
STATEN ISLAND
N
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
463
54B
18
NEW YORK
NEW JERSEY
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 12

GPO 956-592

TOTAL PHYTOPLANKTON VARIATION & ABUNDANCE
3 STATIONS-RARITAN BAY

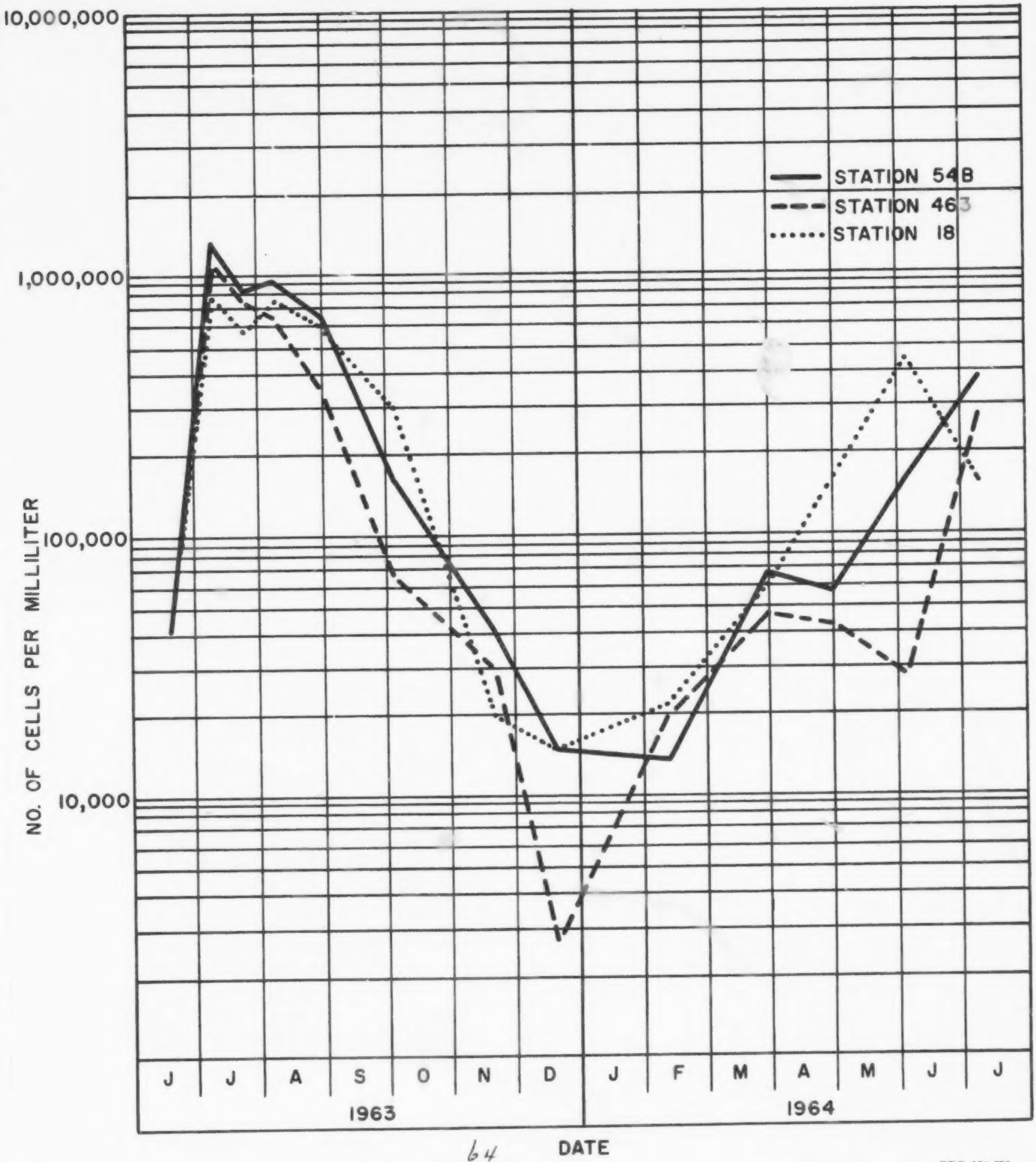


FIGURE 13

GPO 956-592

Netplankton blooms occurred during the colder months, disappearing as temperatures reached 8 or 9°C; hence, netplankton densities were lowest during the summer and greatest in the spring. At their peak, spring blooms of netplankton constituted 27 to 48% of the total plankton population. In both 1962 and 1963 blooms of netplankton occurred during the first week of October at Station 18. Such fall blooms are a normal occurrence in coastal waters.

Phytoplankton densities during 1963 blooms were twice those found during blooms in 1964, but it was noted that water temperatures in 1963 were 1 to 2°C higher at the time of the peak bloom.

Phytoplankton populations were dominated by two algal species, *Nanochloris atomus* and *Skeletonema costatum*. The former, a green alga, comprised more than 50 to 99.9% of the nanoplankton community. *Skeletonema costatum*, a diatom, comprised from less than 1.0 to more than 99% of the netplankton population. During August and September 1962, and again in 1964, a dinoflagellate, *Peridinium trochoidum*, numerically dominated the netplankton population. This alga was not observed in quantitative samples collected during the summer of 1963.

In quantitative samples, no more than 20 different phytoplankters were observed at any one station at one time. The maximum number of species occurred in late spring, while minimal numbers were found in autumn. Generally, fewer species were found towards the western end of the Bay than in the seaward end. Occasionally, a fresh water species was observed at all stations.

Large numbers of zooplankton were found from November 1963 to August 1964. In general, zooplankton density decreased from Station 18 to Station 463. Maximum density variation was observed at Station 54B. Zooplankton densities exhibited seasonal patterns paralleling both water temperature and blooms of netplankton. The plentiful supply of phytoplankton from such blooms enabled the zooplankton population to achieve high densities.

A small crustacean, the copepod, comprised 72% of the total zooplankton, with the predominant genus being *Arcartia*, which is a true estuarine organism. Other major components of the zooplankton population were found to be rotifers and larval benthos. During December 1963, 38% of the total zooplankton population at both Station 463 and 54B was formed by a rotifer commonly found in the Raritan River. In June 1964 a different rotifer, presumably from both the Raritan River and Arthur Kill, comprised 74% of the zooplankton population at Station 54B, 6% of that at Station 18, and was present at Station 463; thus indicating an outward movement of this organism during the summer months. Both copepods and rotifers were found in concentrations in excess of 100,000 per cubic meter. In late May and early June 1964, juvenile copepods of the *Arcartia* genus appeared in densities of approximately 100,000 per cubic meter, resulting in a red appearance of the surface water of inner Raritan Bay.

Coincidental with plankton studies, levels of selected nutrients were determined at each of the plankton stations. Results of these analyses are presented in Table XI. These selected nutrients were always present in amounts sufficient to support the observed plankton populations. Nutrient levels were generally highest at Station 463 and lowest at Station 18. High concentrations of phosphate were found at Station 54B, while Station 463 showed nitrite and nitrate concentrations higher than the other stations.

Benthic Studies

During 1963 and 1964 benthic samples were collected in Raritan Bay and were subjected to both chemical and biological analyses. During the summer of 1963 one benthos sample was collected at each of the stations shown in Figure 14. The bottom sediment was classified according to median grain size. Those stations with sediment composed of the smallest size particles had fewer animals than those areas with the larger grain size.

The Bay area was divided into the five sections shown in Figure 14. Section A was designated as the pollution source area and sections B, C, D, and E were located respectively 0.5, 1.0, 2.0, and 5.0 miles from Section A. The only median grain size found common to all sections was the 30 micron or smaller category. Figure 15 presents the average density of benthic organisms and the number of different species found in each section. For all median grain size categories the number of individuals and the numbers of species increased progressively with distance from Section A.

During 1964 benthic studies were made utilizing only those stations with sediment having a median grain size of 30 microns or less. Figure 16 shows the location of the stations utilized. Stations 61, 62, and 65 were located in the most polluted area of the Bay; Stations R, B, and 29 in less polluted areas. Stations H and 15, located in an area open for commercial shellfishing, were in relatively clean water.

Results in 1964 confirmed those of the previous year as progressively more species were found with increasing distance from the western end of Raritan Bay. The number of species in polluted areas were markedly fewer than in those areas regarded as non-polluted. Figure 17 shows the pattern of progressive colonization moving westerly across the Bay between February and August. In February 1964, benthic animals were found only at the three outermost stations —— 29, H and 15; by August all stations had become populated. During the same period there was an increase in both temperature and chlorinity paralleling this progressive colonization. The density of organisms displayed a pattern similar to that for the total number of species found. More organisms were found furthest away from Stations 62, 65 and 61, with the exception of August 1964 when quantities of the softshell clam, *Mya arenaria* —— a highly pollution tolerant organism —— was found at Stations 62 through B.

The types of benthic organisms and their relative numbers are presented in Table XII. The polychaete, or segmented worms and anthropod crustaceans were the dominant benthic organisms. Tube dwelling worms, regarded as pollution tolerant organisms, were more numerous towards Stations 62 and B, indicating a greater degree of pollution in that area.

In May and August 1964, certain chemical analyses were performed on samples of bottom sediment. A comparison was made between these data and the average number of benthic species found at each station. With the exception of Station H the results presented in Figure 18 indicate a general decline in the level of Total Kjeldahl Nitrogen, BOD and COD with increasing distance from the more polluted stations. The higher concentrations at H were attributed to a small sewer outfall located in the immediate vicinity. In general, fewer benthic species were found at those stations having the higher concentrations of nitrogen.

Color and Turbidity

The color of water in Raritan Bay was found to be frequently associated with dominant phytoplankton populations. During the summer of 1963 for example, the predominant alga Nanochloris imparted a turf grass green color to the water. During the late winter and spring the water was a brownish color due to an abundance of a diatom, Skeletonema costatum. In July 1964 the water of the inner part of Raritan Bay had a reddish color due to an abundant flagellate growth.

Turbidity at three stations in Raritan Bay, as measured by Secchi disc transparency, is illustrated in Figure 19. Turbidity appeared to be independent of plankton density and was due mainly to large amounts of detritis.

TABLE XI

RARITAN BAY NUTRIENTS

Station	463			54B			18		
1963	NO_2^- N	NO_3^- N	PO_4 *	NO_2^- N	NO_3^- N	PO_4^- P	NO_2^- N	NO_3^- N	PO_4^-* P
Mar.	--	0.65	0.14	--	--	--	--	0.39	0.06
Apr.	--	0.15	0.07	--	0.07	0.26	--	--	--
May	0.06	0.34	0.11	--	0.21	0.10	0.02	0.11	0.09
June	0.08	0.44	0.15	0.07	0.27	0.14	0.04	0.16	0.08
July	0.10	0.19	0.14	0.04	0.07	0.18	0.02	0.05	0.13
Aug.	0.11	0.16	0.19	0.06	0.09	0.24	0.04	0.05	0.17
Sept.	0.20	0.44	0.06	0.06	0.18	0.18	0.04	0.14	0.16
Nov.	0.07	0.49	0.14	0.08	0.50	0.12	0.07	0.39	0.13
1964									
May	0.04	0.08	0.12	0.03	0.07	0.11	0.02	0.09	0.13
June	0.07	0.13	0.14	0.06	0.06	0.15	--	--	--
July	0.10	0.27	0.16	0.06	0.15	0.16	0.03	0.05	0.14
Nov.	0.09	0.43	0.24	0.12	0.25	0.24	0.07	0.04	0.22
Av.	0.09	0.31	0.14	0.06	0.17	0.17	0.04	0.15	0.13

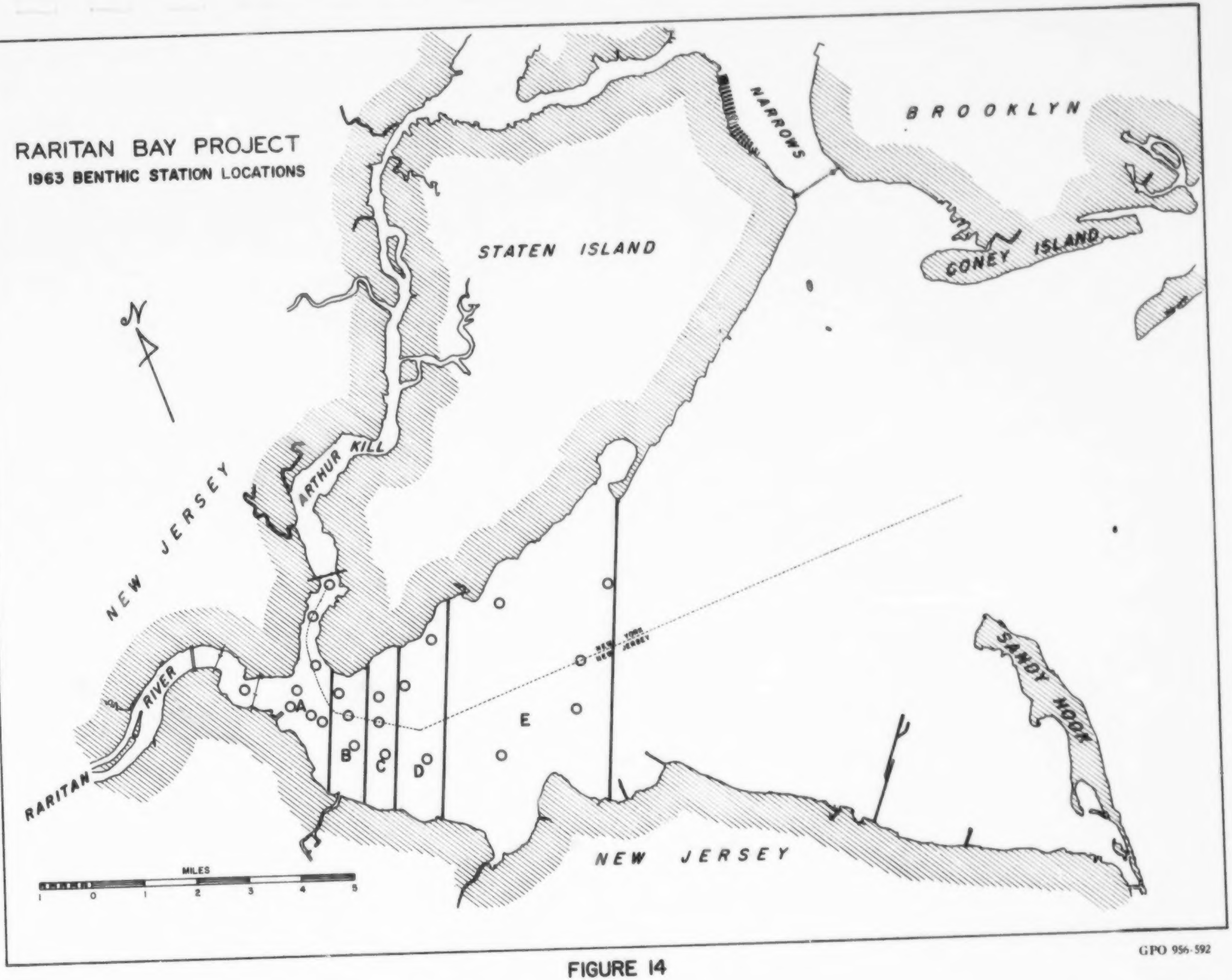
* Phosphate = ortho & poly (soluble)

TABLE XII

PERCENTAGE OF BENTHOS AT REPRESENTATIVE STATIONS

	Station 62				Station B				Station 29				Station H			
1964	PW	AC	SC	O	PW	AC	SC	O	PW	AC	SC	O	PW	AC	SC	O
Feb.	0	0	0	0	76	6	0	18	67	17	0	16	8	92	0	0
May	100	0	0	0	65	15	0	20	33	66	0	1	15	85	0	0
Aug.	0	0	100	0	35	28	10	27	74	19	7	0	55	38	0	7

PW = Polychaete Worms
AC = Amphipod Crustaceans
SC = Soft Shell Clams
O = Others: All types of organisms that comprised separately less than 5% of the total.



RARITAN BAY PROJECT
1963 BENTHIC STATION LOCATIONS

N
BROOKLYN
NARROWS
STATEN ISLAND
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
NEW YORK
NEW JERSEY
A
B
C
D
E
SANDY HOOK
NEW JERSEY
MILES
1
0
1
2
3
4
5

FIGURE 14

GPO 956-592

BENTHOS AVERAGE DENSITY & NUMBER OF SPECIES
JUNE-AUG. 1963

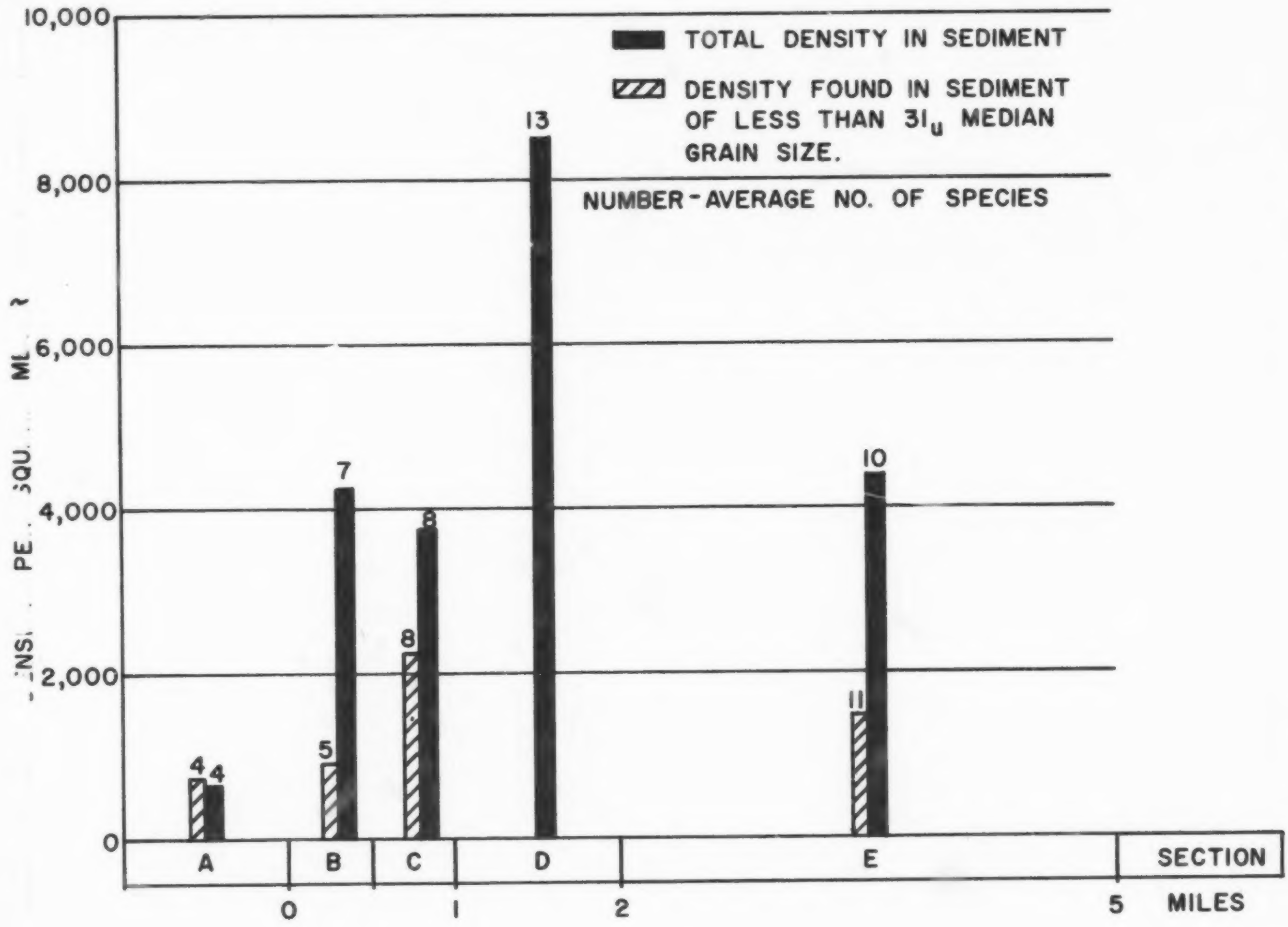
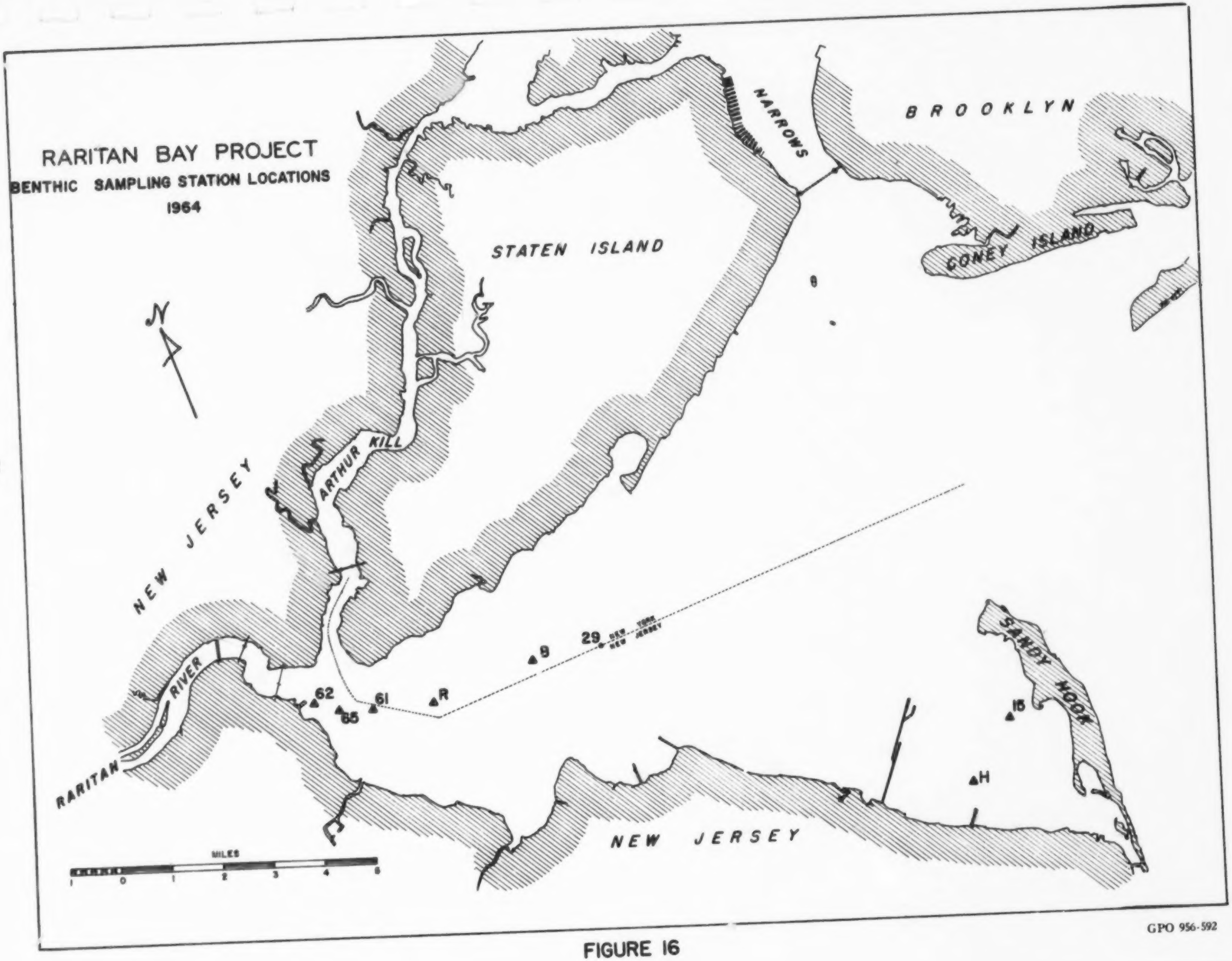


FIGURE 15

GPO 956-592



RARITAN BAY PROJECT
BENTHIC SAMPLING STATION LOCATIONS
1964
N
STATEN ISLAND
BROOKLYN
NARROWS
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW YORK
NEW JERSEY
62
65
61
R
9
29
15
H
NEW JERSEY
MILES
1
0
1
2
3
4
5

FIGURE 16

GPO 956-592

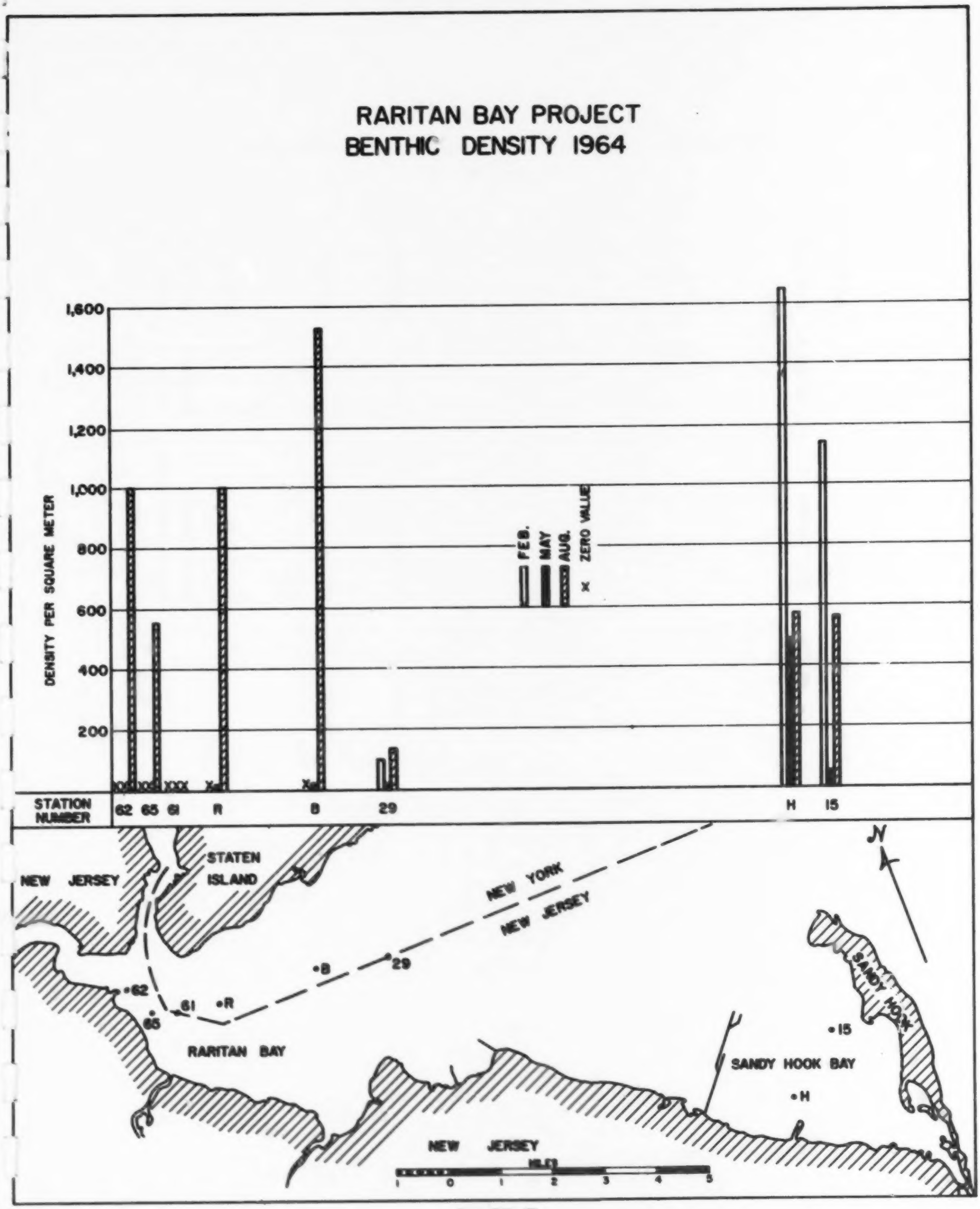

RARITAN BAY PROJECT
BENTHIC DENSITY 1964
DENSITY PER SQUARE METER
1,600
1,400
1,200
1,000
800
600
400
200
FEB.
MAY
AUG.
ZERO VALUE
X
STATION NUMBER
62
65
61
R
B
29
H
15
NEW JERSEY
STATEN ISLAND
NEW YORK
NEW JERSEY
RARITAN BAY
SANDY HOOK BAY
SANDY HOOK
NEW JERSEY
N
MILES
1
0
1
2
3
4
5

FIGURE 17

73

RARITAN BAY PROJECT
CHEMICAL & BIOLOGICAL SEDIMENT ANALYSIS

MAY AND AUGUST 1964

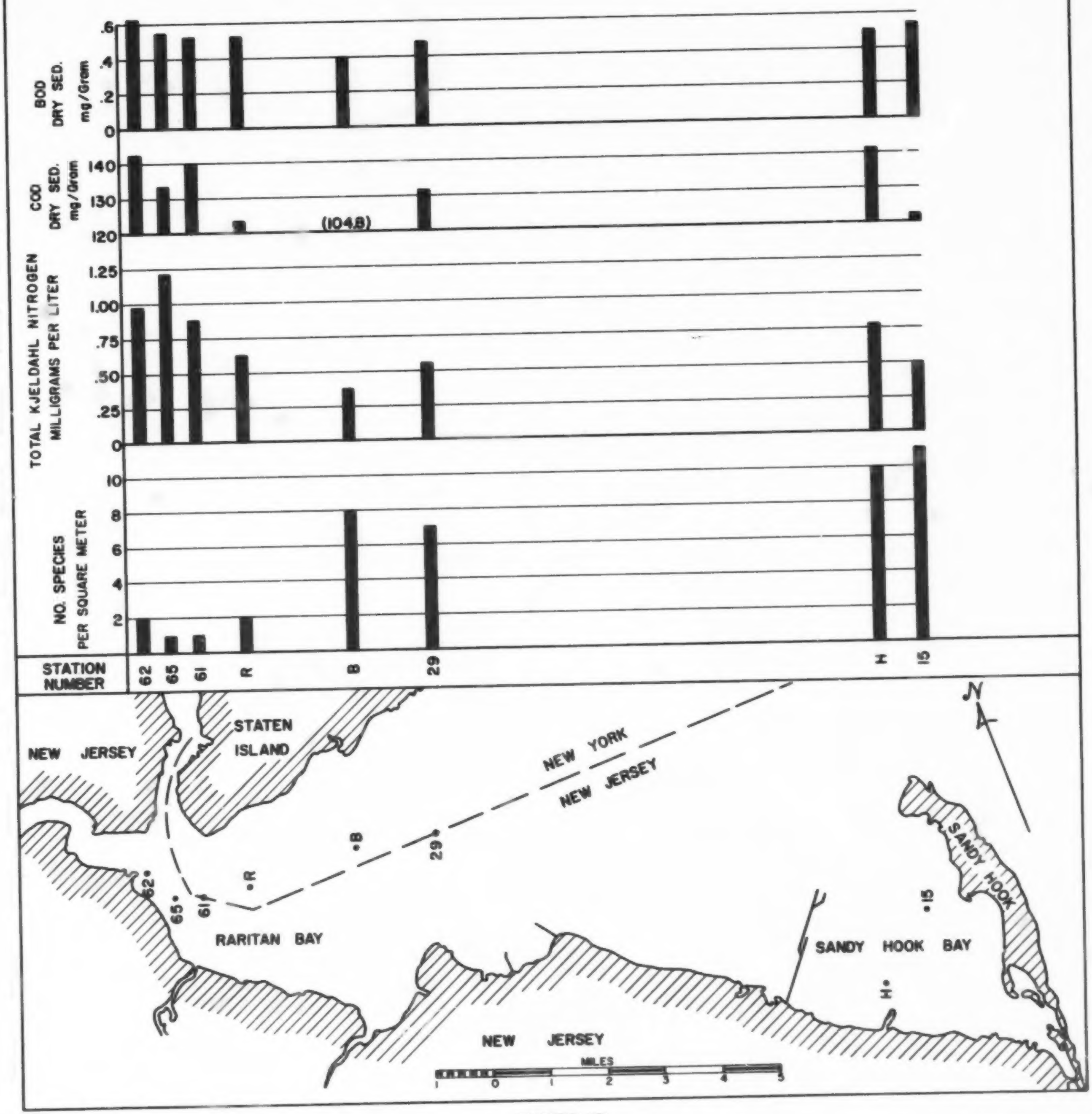


FIGURE 18

TURBIDITY, RARITAN BAY

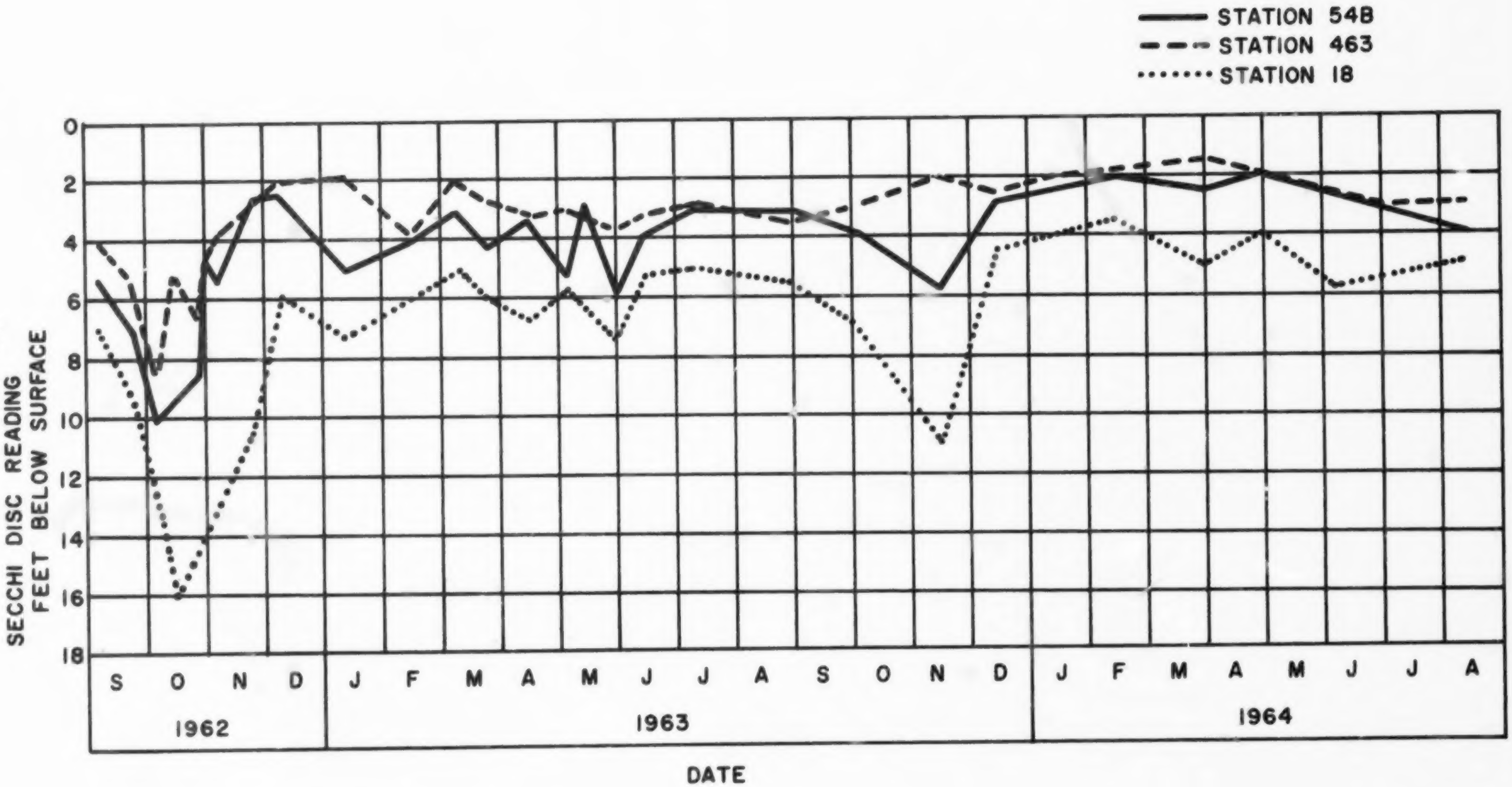


FIGURE 19

GPO 956-592

Arthur Kill

Water Temperature

Average water temperatures ranged from 12 to 16°C, as shown in Figure 20. Temperatures as high as 28°C were observed; maximum water temperatures over the entire length of the Kill were greater than 26°C. The average water temperature declined gradually proceeding north through the Kill into Newark Bay —— warmest temperatures were found in the southern portion of the Kill.

Chloride

Average chloride concentration at the lower end was 13,500 mg/l. Chlorinity declined proceeding northward with an average value of 11,500 mg/l at the junction with Newark Bay. From this point to Upper Bay there was in increase in chloride concentration through the Kill Van Kull.

During the surveillance period the same spatial pattern was observed. Slight increases in mean values were noted near the middle reach of the Kill. Minima concentrations also increased, but maxima were unchanged. These observed changes may be explained by a decrease in fresh water run-off due to the prolonged drought period.

BOD_5

Average BOD concentrations ranged from 3 mg/l at Outerbridge Crossing to 6 mg/l north of Station 502, which is located near the center of the Kill. At the junction of the Kill and Newark Bay BOD values decreased to 3 mg/l. Maximum BOD values of 12 mg/l were found near the center of the Kill.

Analyses of BOD at increasing dilutions indicated an apparent toxic effect upon the exertion of BOD in the Kill. Hence, results are not completely indicative of the oxygen demanding load. The presence of large quantities of phenols may account for this apparent inhibition of BOD exertion.

Because of this observed toxicity, COD was substituted for BOD during the surveillance operations.

COD

Results of analyses for chemical oxygen demand on the Arthur Kill are presented in Figure 21. Average COD values throughout the Kill ranged from 110 to 135 mg/l.

During the surveillance period no significant change was observed in the levels or spatial pattern for COD.

Dissolved Oxygen

The average dissolved oxygen concentrations during the intensive sampling period of August 1962 through September 1963 are presented in Figure 22. Average concentrations of 6 mg/l were found at Outerbridge with a decline to an average of 2.5 mg/l from Stations 503 to 520, and a recovery to 3.5 mg/l at the entrance to Newark Bay. Minimum values were zero from Stations 504 to 507.

Studies were undertaken to determine the net effect of photosynthetic production of oxygen (See Figure 23). Total oxygen uptake at Station 503 significantly reduced the net oxygen yield from photosynthesis. At Station 505 more oxygen was utilized than could be produced by photosynthesis. Oxygen production was insignificant below eight feet. On a total basis more oxygen was produced by photosynthesis in Arthur Kill than in Raritan Bay. Oxygen uptake in the Kill was three times greater than in the Bay, resulting in a net apparent yield of oxygen in the Kill of only one-tenth of that found in Raritan Bay. Only 5.0% of the total oxygen produced by photosynthesis in the Arthur Kill was available to the water.

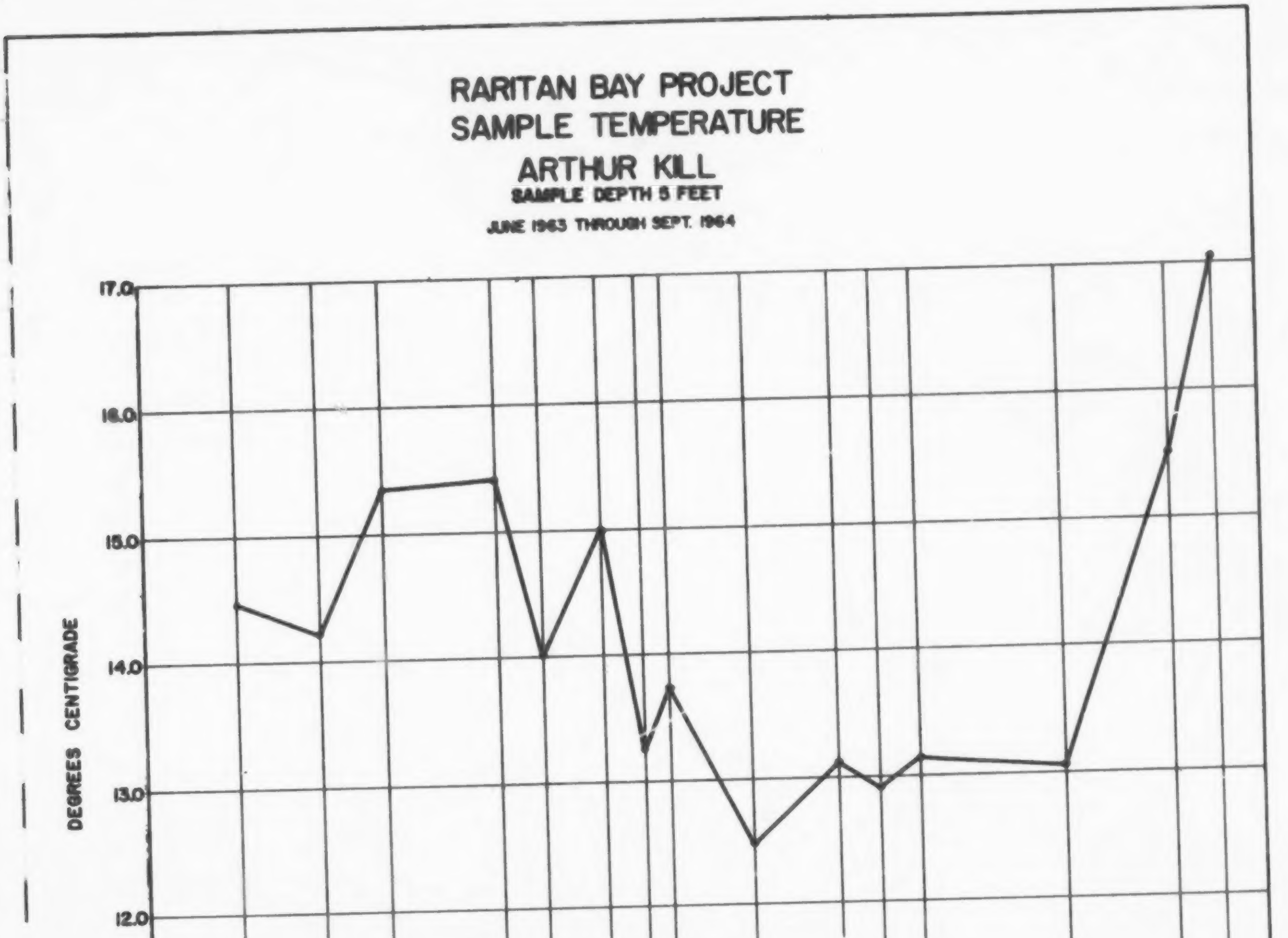
Additional studies were conducted to determine the effect of commercial dredging on dissolved oxygen concentrations. On two separate occasions measurements were taken during dredging operations (See Figure 24). Dissolved oxygen levels were lowest at the dredging site and lower in the vicinity of the dredging operation than elsewhere in Kill. The average dissolved oxygen concentrations for non-dredging periods between December 1963 and March 1964 were higher than those noted during dredging.

Surveillance of the Kill indicates a continued decline in dissolved oxygen levels. Mean concentrations were reduced to 1.1 mg/l near Station 520, with recovery to only 2.6 mg/l at Newark Bay. Minima of less than 0.5 mg/l were observed from Outerbridge to Kill Van Kull.

Phenol

Concentrations of phenolic-type compounds as high as 800 ppb were found in the vicinity of Fresh Kills and the Rahway River. Phenol values in the middle reach of the Kill were two to three times greater than the levels found at the northern and southern extremities. Average phenol concentrations for the intensive sampling period are presented in Figure 25.

During the surveillance period mean phenol concentrations increased to 105 ppb at the peak locations near Stations 505 and 520, while mean concentrations near the entrance to Raritan Bay decreased slightly. Minima concentrations increased, while maxima values remained constant.



RARITAN BAY PROJECT
SAMPLE TEMPERATURE
ARTHUR KILL
SAMPLE DEPTH 5 FEET
JUNE 1963 THROUGH SEPT. 1964

FIGURE 20

RARITAN BAY PROJECT
CHEMICAL OXYGEN DEMAND
ARTHUR KILL
SAMPLE DEPTH 5 FEET

MEAN FOR
AUG. 1962 THROUGH SEPT. 1964

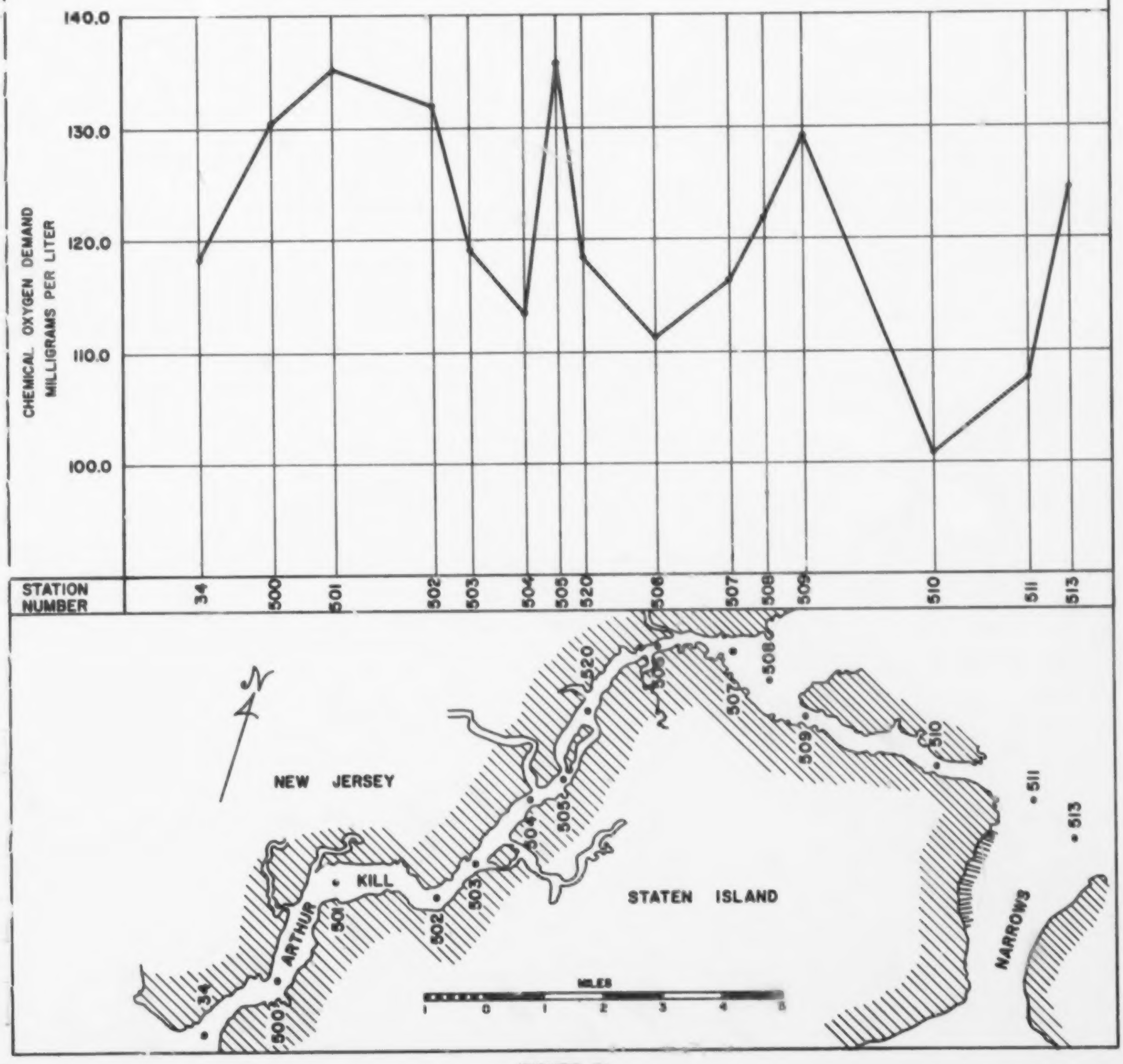


FIGURE 21

RARITAN BAY PROJECT
DISSOLVED OXYGEN
ARTHUR KILL

SAMPLE DEPTH 5 FEET

JUNE 1963 THROUGH SEPT. 1964

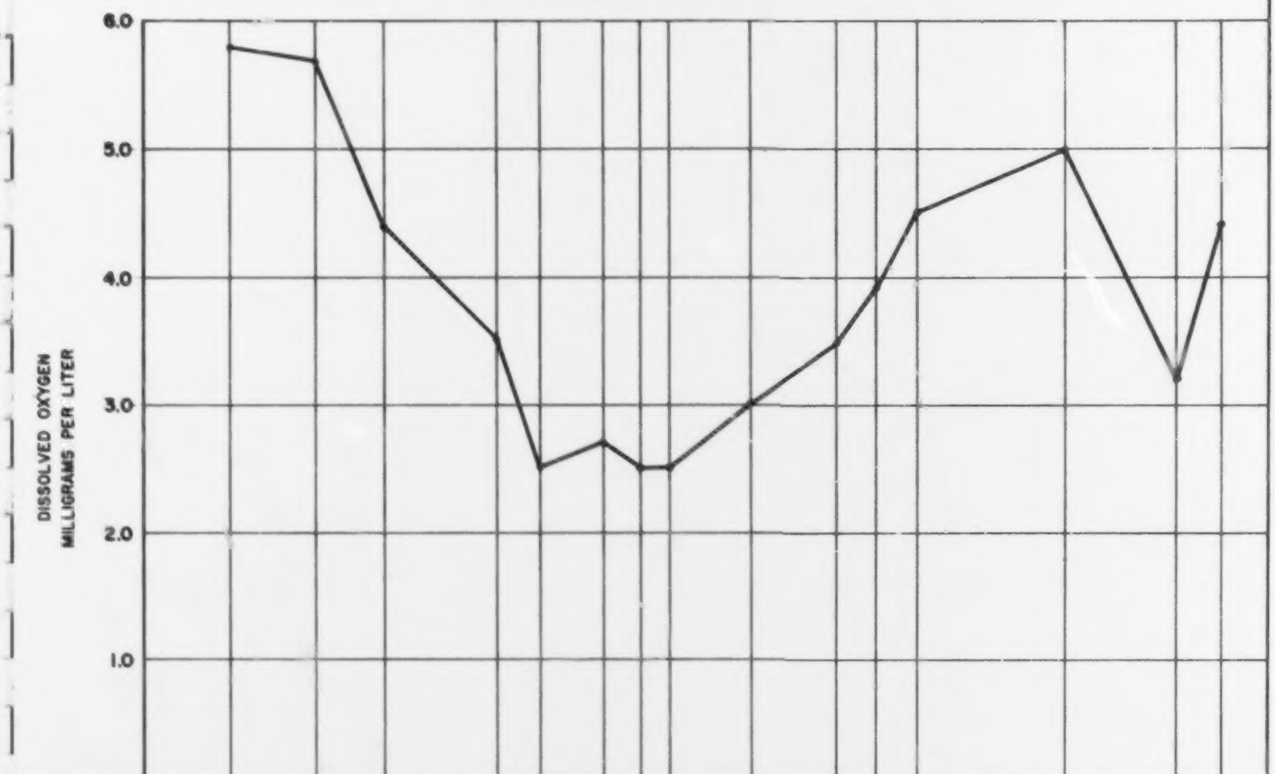


FIGURE 22

GPO 956-592

OXYGEN PRODUCTION, UPTAKE & YIELD

PHOTOSYNTHETIC ZONE

ARTHUR KILL

AUGUST 1964

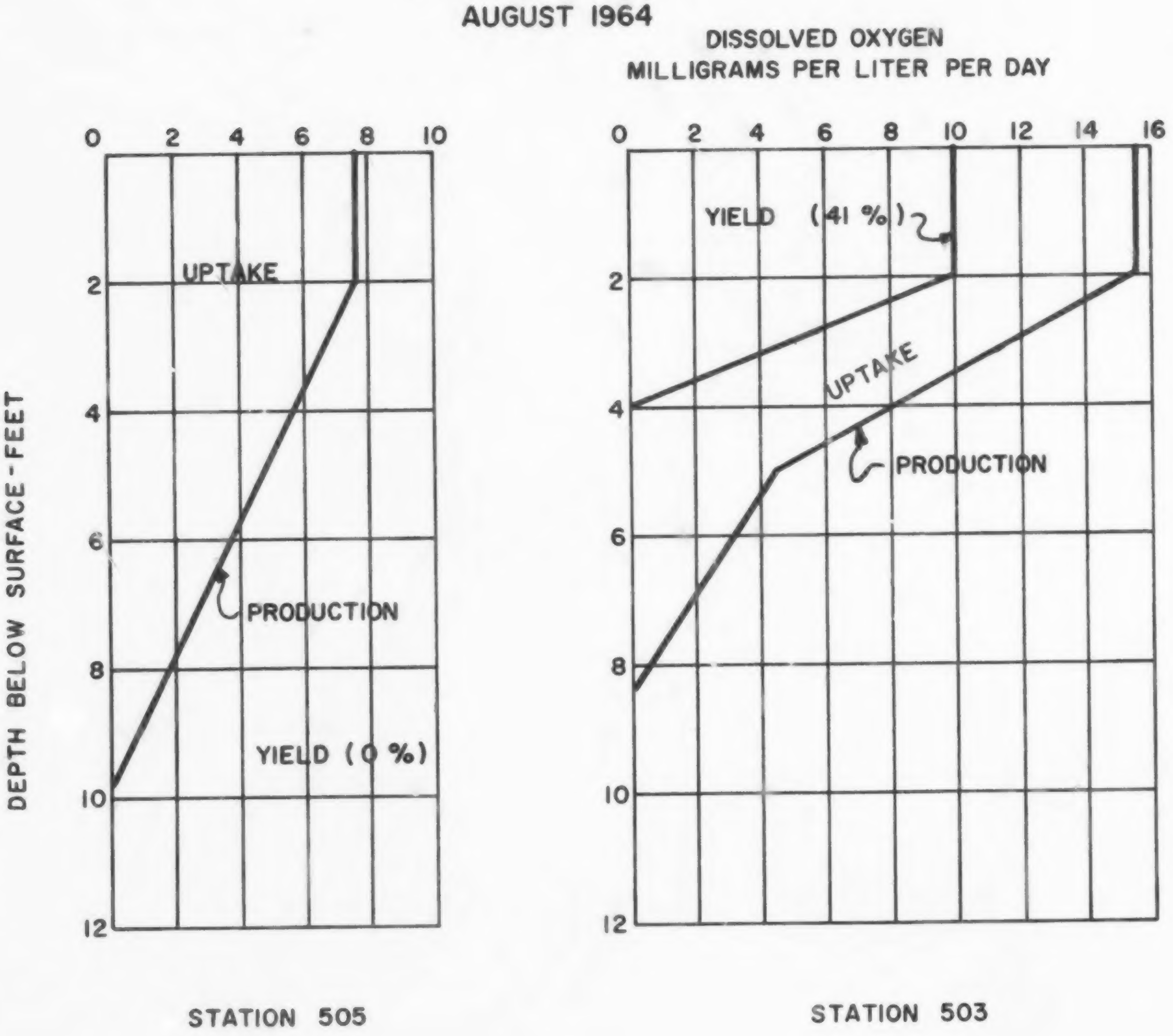


FIGURE 23

GPO 956-592

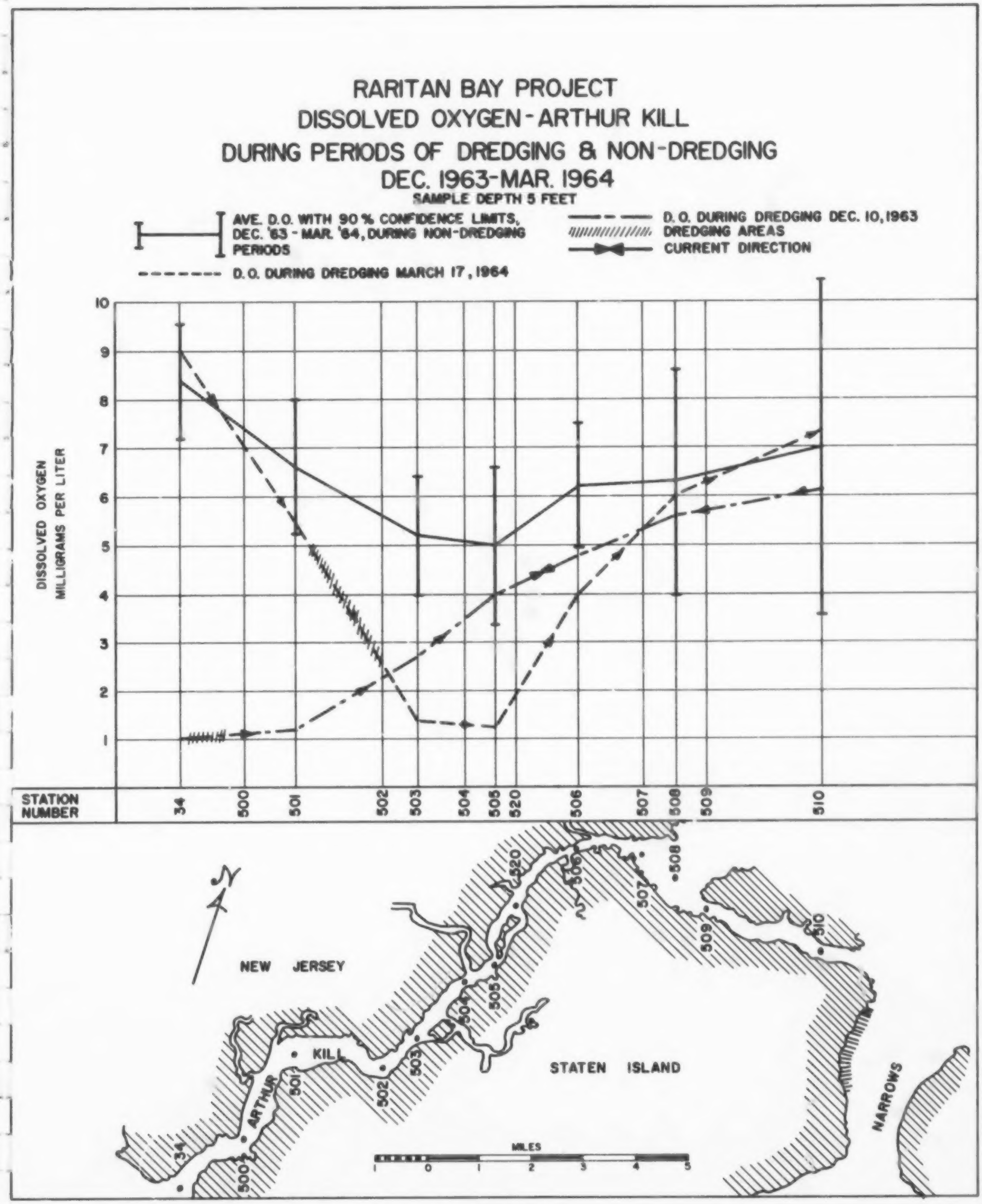

RARITAN BAY PROJECT
DISSOLVED OXYGEN - ARTHUR KILL
DURING PERIODS OF DREDGING & NON-DREDGING
DEC. 1963 - MAR. 1964
SAMPLE DEPTH 5 FEET

FIGURE 24

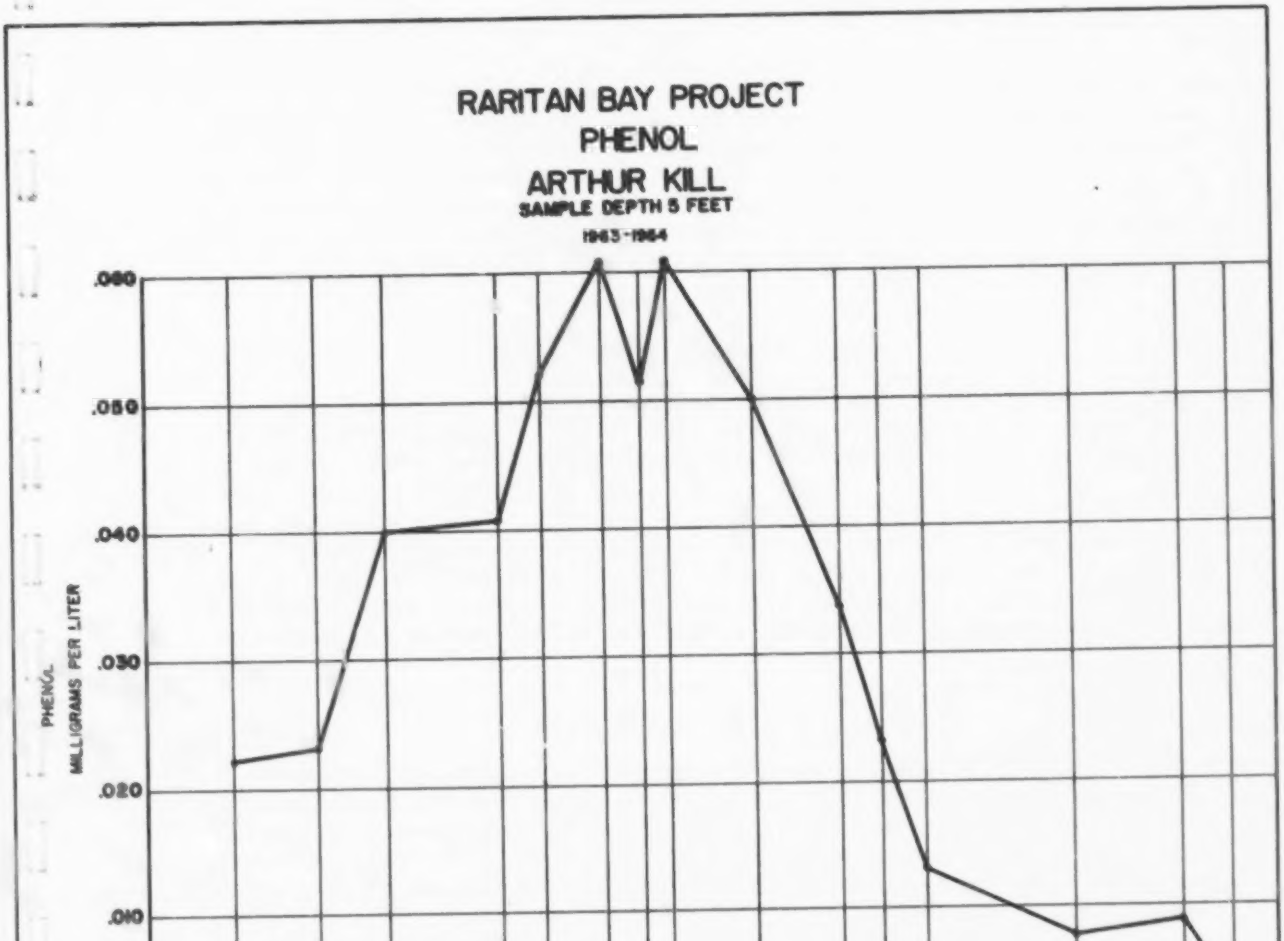

RARITAN BAY PROJECT
PHENOL
ARTHUR KILL
SAMPLE DEPTH 5 FEET
1963-1964
PHENOL
MILLIGRAMS PER LITER
.060
.050
.040
.030
.020
.010
STATION NUMBER
34
500
501
502
503
504
505
520
506
507
508
509
510
511
513
N
NEW JERSEY
KILL
ARTHUR
STATEN ISLAND
NARROWS
MILES
1
0
1
2
3
4
5

FIGURE 25

Oil

Although no quantitative analyses were made, oil was frequently observed on the Kill surface. Mud samples were collected and an attempt was made to recover oil from this bottom material. Results, presented in Table XIII, indicate a heavy deposit of oil on the bottom of the Kill. The maximum oil recovery in the Kill was at Station 505 where 1 gram of oil was recovered from 50 gms of dry bottom mud. In Woodbridge Creek, a tributary to the Kill, 32 grams of oil were recovered from 50 grams of the dry mud.

Bacteriological Density

Results of limited bacteriological sampling on the Arthur Kill are presented in Figure 26. Total coliform, fecal coliform and fecal streptococcus values indicate severe bacteriological contamination of these waters from human wastes.

During surveillance studies MF coliform showed a slight increase in the reach from Station 503 to Raritan Bay and a decrease in the Kill Van Kull. Fecal coliform values remained within the limits observed earlier, with some reduction in minima values from Station 513 to Station 504.

Plankton and Nutrients

Average phytoplankton density and a comparison of total and net phytoplankton for each station on the Kill are presented in Figure 27. Throughout the biological sampling period of October 1963 through September 1964 total phytoplankton density increased progressively from Station 34 to Station 508 and then decreased at Station 510. Netplankton concentrations at Station 510 were ten times lower than at Station 34. Of the total phytoplankton, nanoplankton comprised 95% and characterized the period of maximum density. Netplankton densities were highest during the spring bloom of _Skeletonema costatum_, the principal netplankton species. During late spring, summer and autumn diatoms of the genus _Thallassiosira_ predominated.

Zooplankton populations are presented in Figure 28. Populations at Stations 503, 505 and 506 were 38% less than elsewhere on the Arthur Kill-Kill Van Kull. The number of different species of zooplankton was also reduced at these three stations. Zooplankton populations appeared to be dependent on water temperature and the abundance of phytoplankton rather than chloride concentrations. The majority of zooplankton observed were types able to adjust to wide ranges of salinity. There was a marked increase in the number of zooplankton with the spring and summer period, when an abundant diatom flora and warmer water temperatures appeared. The locational distribution of zooplankton appeared dependent on dissolved oxygen concentrations which would inhibit their growth since zooplankton are active respirators. Lowest zooplankton densities occurred at Station 505 simultaneously with lowest dissolved oxygen concentrations.

TABLE XIII

OIL RECOVERIES FROM BOTTOM MUDS
ARTHUR KILL

Station	Oil Recovery Grams Per 50g Dry Mud
34	0.04
500	0.08
Woodbridge Creek	31.93
501	0.02
502	0.39
503	0.18
504	0.54
505	1.13
520	0.02
507	0.05

Note: 1. Samples collected by Petersen dredge Sept. 10, 1964.

2. Analysis consisted of Soxhlet extraction with cyclohexane.

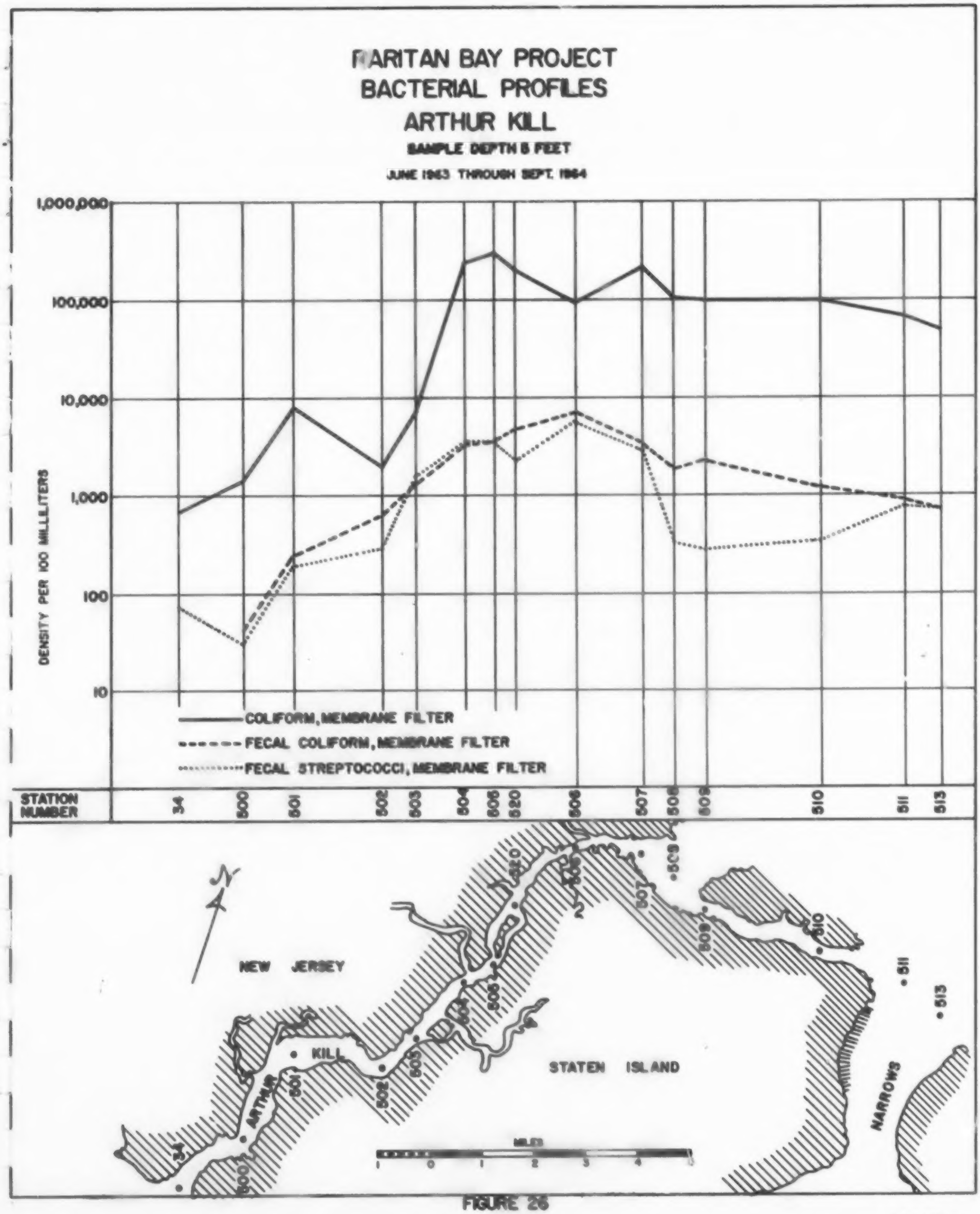

RARITAN BAY PROJECT
BACTERIAL PROFILES
ARTHUR KILL
SAMPLE DEPTH 5 FEET
JUNE 1963 THROUGH SEPT. 1964
1,000,000
100,000
10,000
1,000
100
10
DENSITY PER 100 MILLILITERS
COLIFORM, MEMBRANE FILTER
FECAL COLIFORM, MEMBRANE FILTER
FECAL STREPTOCOCCI, MEMBRANE FILTER
STATION NUMBER
34
500
501
502
503
504
505
520
506
507
508
509
510
511
513
N
NEW JERSEY
STATEN ISLAND
ARTHUR
KILL
NARROWS
MILES
1
0
1
2
3
4
5

FIGURE 26

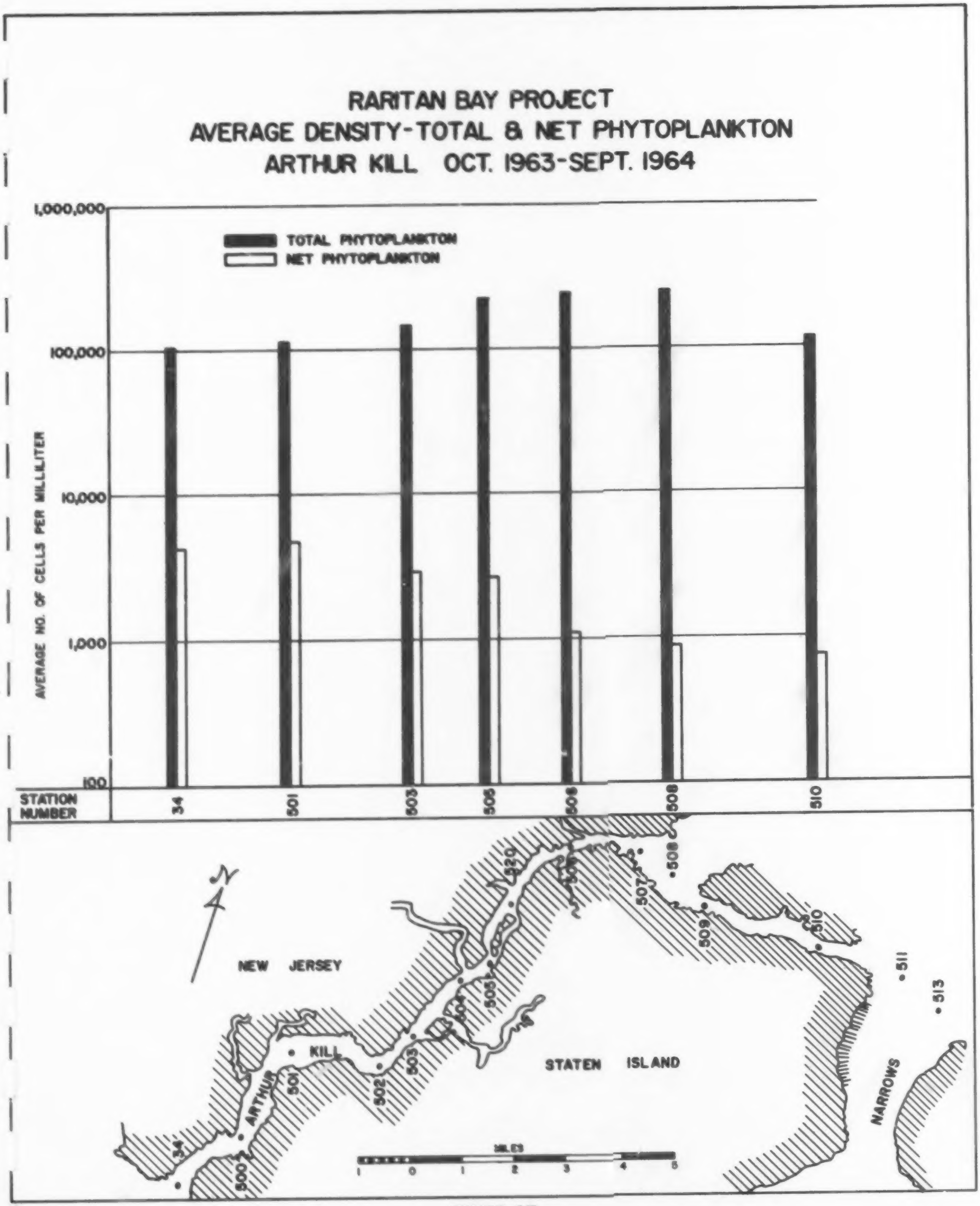

RARITAN BAY PROJECT
AVERAGE DENSITY-TOTAL & NET PHYTOPLANKTON
ARTHUR KILL OCT. 1963-SEPT. 1964

FIGURE 27

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RARITAN BAY PROJECT
DENSITY & NUMBER OF SPECIES FOR ZOOPLANKTON
ARTHUR KILL OCT. 1963 - SEPT. 1964

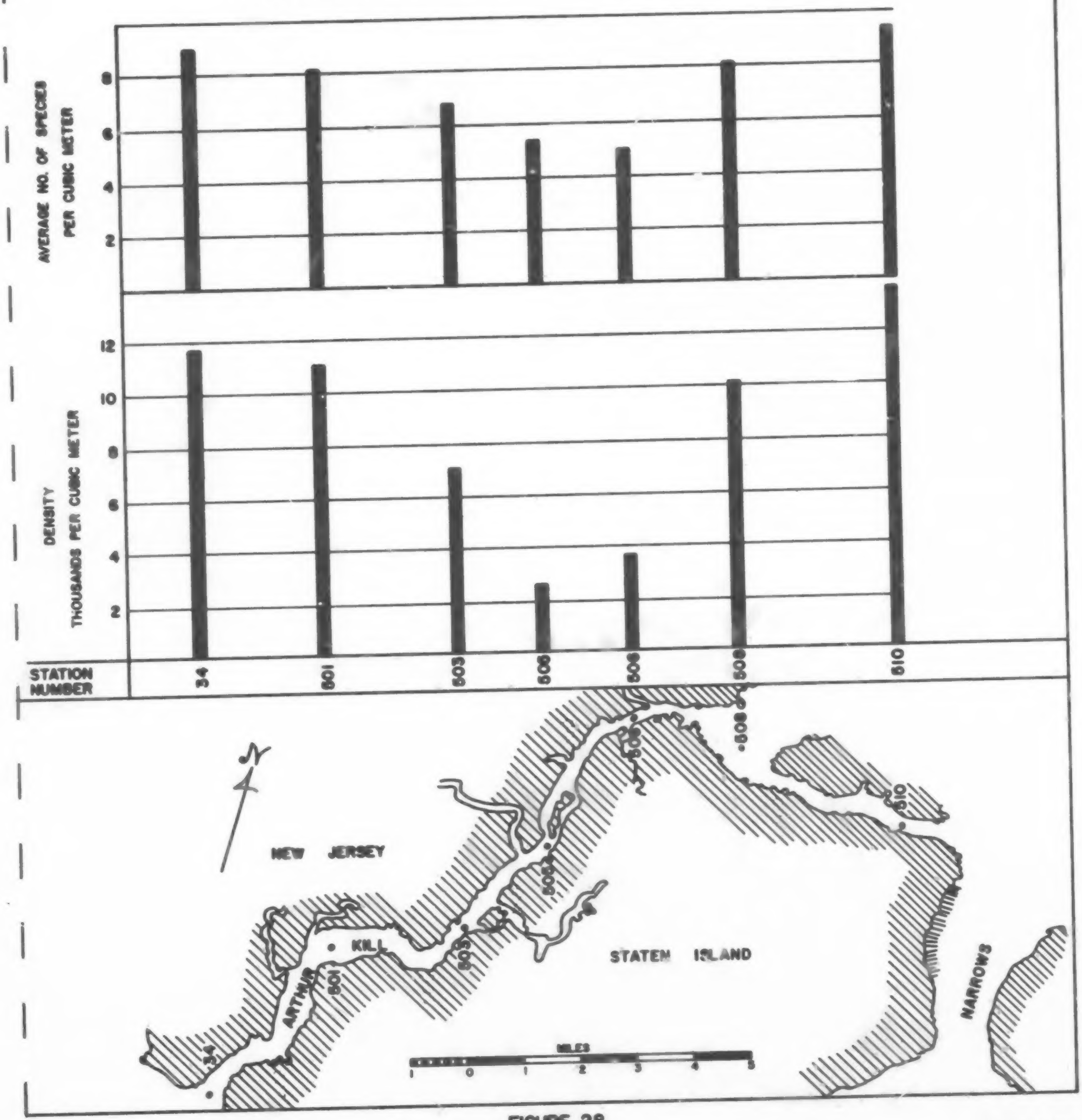

FIGURE 28

GPO 956-592

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Figure 29 presents the seasonal variation in selected nutrients for the Arthur Kill. At no time were nutrient levels below the minimum necessary to support phytoplankton growths.

A review of data collected during surveillance shows no significant changes in spatial patterns or levels of phosphate, nitrate or nitrite.

Benthic Studies

Table XIV presents results of studies of benthic organisms. The 11 miles of bottom from Station 501 to 509 was devoid of benthic animals. The three sampling runs made on October 1 and November 14, 1963 and June 15, 1964 showed little variation in either density of organisms or species found. Benthic organisms were never found in excess of 800 per square meter, nor were more than seven different species present at any station.

Dominant organisms were tube dwelling segmented worms principally *Polydora lignii* and the softshell clam, *Mya arenaria*, both of which are considered pollution tolerant organisms. Remains of dead benthic organisms were absent from Stations 502 to 508, suggesting that animals were unable to survive.

The only plant materials observed between Stations 502 and 508 were the remains of land plants. Bottom material from all stations had an oily odor which was more intense between Stations 501 and 510. Bottom materials from Stations 508 through 510 also had the characteristic odor of hydrogen sulfide.

Bioassay

From June 24 to July 1, 1964 a field bioassay study was conducted. Three types of test organisms —— killifish, mud crab and shrimp —— were immersed in cages at four stations in the Kill and at a station in Princess Bay, Staten Island, N.Y., which served as a control for the test. In addition to live caged animals, traps were placed at the same locations to permit observation of growth of the attached organisms. Results of this study are presented in Table XV.

At the control station in Princess Bay, 85% of the test organisms survived after seven days' exposure. At Stations 504 and 520 in the Arthur Kill-Kill Van Kull no organisms survived after two days. Survival at Station 507 was less than at Station 500. After two days no attached growth had formed on traps at Stations 504, 520 and 507, while those at Station 500 and at the control station in Princess Bay had heavy growths. Those stations with the shortest survival times also had the lowest dissolved oxygen concentrations.

To evaluate possible toxicity of Arthur Kill water itself, rather than in conjunction with dissolved oxygen levels, test organisms were left for 48 hours in constantly aerated water taken from the various survival test stations. All organisms survived this experiment.

In other lab experiments test organism survival was limited to several hours in Arthur Kill water when the oxygen content at the beginning of the experiment was 1.0 mg/l and no aeration was allowed. Further, survival was longer at 17°C than at 22°C.

Tests suggest that the observed toxicity to aquatic life in the Kill is due at least in part to the low levels of dissolved oxygen.

Turbidity

Average Secchi disc readings are presented in Figure 30. Average transparency was less than four feet at all stations. Field observations indicated that detritus was frequently the major cause of the observed limited water transparency. This high turbidity restricts the depth of light transmittance and results in limiting oxygen production by photosynthesis to a relatively shallow depth.

TABLE XIV

ARTHUR KILL BENTHOS SURVEY

October 1963

Sta.	Av. No's/M^2	Av. No. Species/M^2	Dominants	Odor	Observations
34	95	1.5	Polychaetes	Slight oil	Small shells (¼"-½"), wood
500	175	5.3	Polychaete	Slight oil	No shells, plant material
501	0		-	Oil	Few *Mya* SHELLS (¼"), plant material
502	3	0.3		Oil	No shells, plant material
503	0		-	Oil	No shells, little plant material
504	0		-	Oil	No shells, little plant material
505	0		-	Oil	Little plant material
520	0		-	Oil	Nothing
506	0		-	Oil	Little plant material
507	0		-	Oil	Nothing else
508	3	0.3	Polychaetes	Oil, H_2S	Nothing else
509	582	4.0	Polychaetes	Oil, H_2S	2 *Mya* shells (1"), little plant material
510	594	8.7	Polychaetes	Oil, H_2S	Plant material

TABLE XV

BIOLOGICAL SURVIVAL STUDY - ARTHUR KILL, JUNE 24-JULY 1, 1964

Station	Organisms In Time Est.	Date	Organisms Out	Number Survived	% Survival	Time Diff. Hrs.	Temp °C In & Out	Salinity %	D.O. mg/1	Observations
Control (Princess Bay)	1130 Fish 3 Crabs 7 Shrimp 10	6-24	1400	7-1 3 5 3 (7 escaped)	84.6	170.5	20.5	24.70	10.15	Plant and animal growth on pilings where trap attached. After 1 week heavy plant and animal growth on trap.
500	12N Fish 3 Crabs 6 Shrimp 1	6-24	1430	7-1 1 5 3 (3 escaped)	75.0	170.5	21.6	23.96	5.30	Plant and animal growth where attached. Heavy plant and animal growth on trap after 1 week.
504	1315 Fish 3 Crabs 6 Shrimp 6	6-24	1135	6-26 0 0 0	0	46.7	23.4	21.41	0.4	Pilings and trap free of growth.
520	1400 Fish 0 Crabs 7 Shrimp 10	6-24	1155	6-26 0 0	0	46.0	23.4	20.71	0.3	Pilings and trap free of growth
507	1340 Fish 3 Crabs 6	6-24	1235	6-26 0 2	13.3	47.0	22.5	21.04	1.3	Algal growth on pilings. Trap free of growth.

SEASONAL NUTRIENT CYCLES-ARTHUR KILL
(AVERAGE FOR ALL BIOLOGY STATIONS)

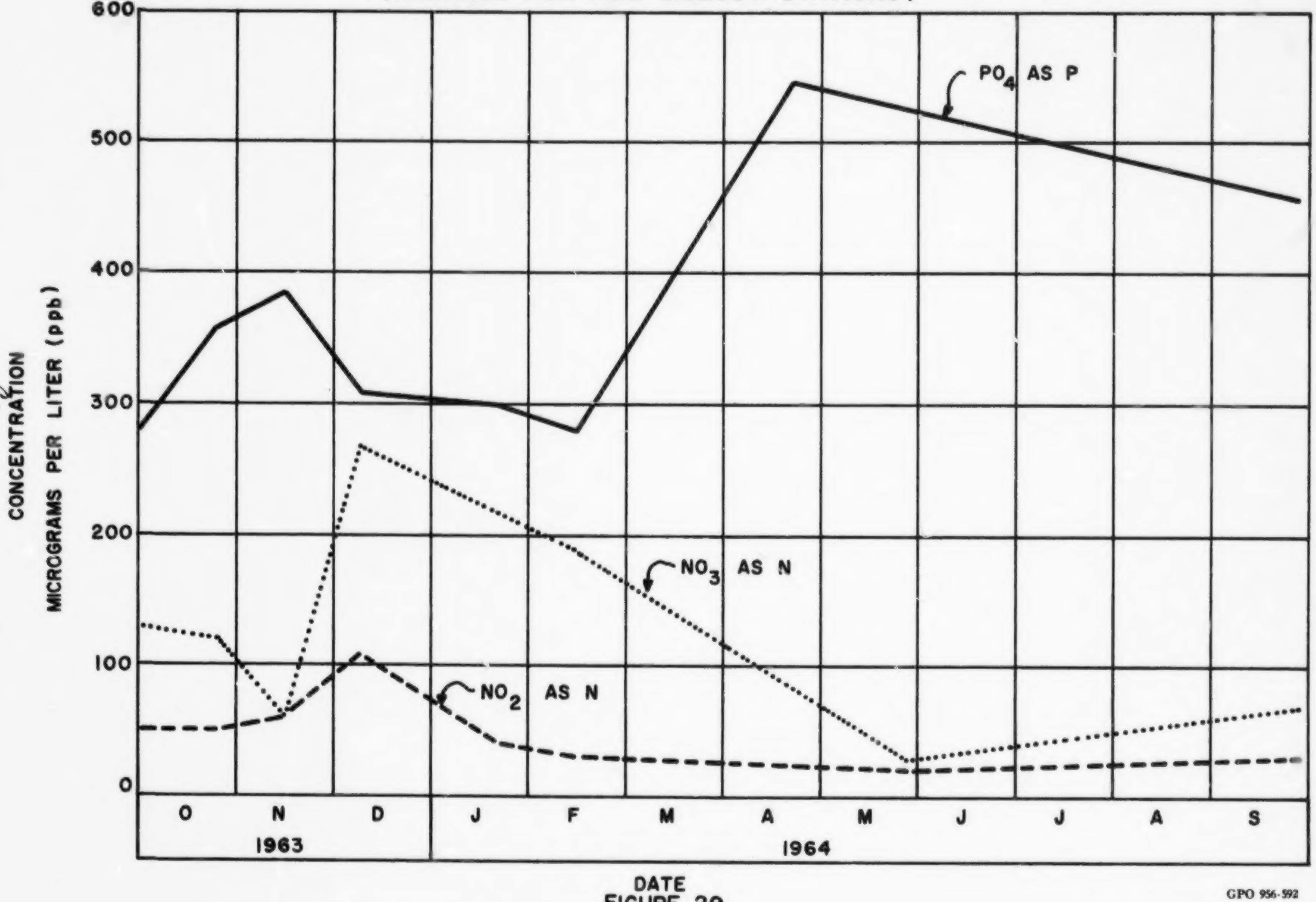


FIGURE 29

GPO 956-592

RARITAN BAY PROJECT
AVERAGE SECCHI DISK READINGS
ARTHUR KILL
OCT. 1963-SEPT. 1964
SAMPLE DEPTH 5 FEET

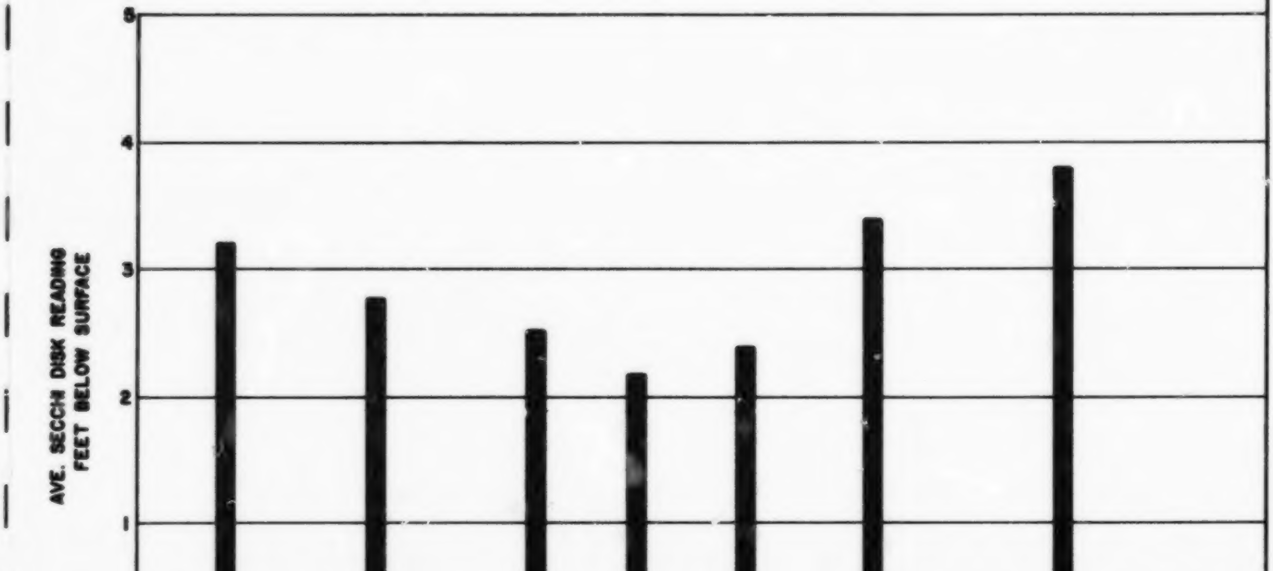


FIGURE 30

GPO 956-592

Raritan River

Presentation of analytical results are based upon data from three sources. Middlesex County Sewerage Authority operates a routine sampling program from Manville to Landing Lane Bridge — river mile 12.8. In 1964 Hydroscience, Inc., Consulting Engineers, conducted a sampling program from mile 10.3 to its mouth. During the period August 5 through September 3, 1964, the Project installed and operated an electronic water quality monitor immediately upstream of the Fieldville Dam at mile 16.4. Discussion of results is based upon data provided by Middlesex County Sewerage Authority and Hydroscience, Inc., for sampling runs performed in July, August, September and October 1964. Results of Project monitoring at Fieldville Dam are presented separately.

Water Temperature

Variation in water temperature is shown in Figure 31. During July, August, and September 1964 it ranged from 22 to 30°C. Considerable variation was found upstream of mile 10.3; however, from this point to the mouth temperature remained relatively constant. Temperatures observed in October 1964 showed less variation with a range of 14 to 16°C over the entire reach of the River.

Chloride

Chloride data were available from mile 10.3 to the mouth at Raritan Bay. In July, August and October 1964 chlorides in this reach ranged from 1,000 mg/l at mile 10.3, to 14,000 mg/l at the mouth. Analyses performed in September 1964 showed a much higher chloride concentration at mile 10.3 with a value of 2,700 mg/l; however, streamflow during this survey was approximately 50% of that observed during the other three months.

BOD_5

Results of BOD determinations for the four runs in 1964 are presented in Figure 32. Maximum BOD was 40 mg/l at mile 18.9, which is immediately downstream of American Cyanamid Dam at mile 19.4. This same location was also the location of maximum BOD concentrations for all runs. Downstream from this point there was a gradual decline in BOD to values of 3 to 4 mg/l at the River mouth. Results for July and September were higher than those observed in August and October.

Dissolved Oxygen

Figure 33 presents dissolved oxygen concentrations observed in the four sampling runs for 1964. A similar pattern, high dissolved oxygen levels upstream of Cyanamid Dam, was observed for all samplings. Downstream from this point to the River mouth results indicate a decline in dissolved oxygen with minimum values between mile point 8.0 and 12.0. A recovery to values of 2 to 6 mg/l occurs near the mouth. The run for

September 1964 showed lowest values with the exception of mile 17.4. On this run, dissolved oxygen was less than 2 mg/l from mile 18.9 to 6.1, and was zero at mile 10.3.

Bacteriological Densities

Results of bacteriological sampling for MPN coliform from mile point 22.3 —— junction of the Millstone River, to mile point 12.8 are presented in Figure 34. At the confluence of the Millstone River MPN coliforms ranged from 200 to 1,100 per 100 ml. With the exception of October 1964, there was a rapid increase in coliforms from this point to the Cyanamid Dam where counts in excess of 110,000 per 100 ml were found. Downstream from this point coliform counts remained high, in no case falling below 1,100 per 100 ml. In September 1964 coliform counts downstream of the Cyanamid Dam were in the Range of 10,000 to 100,000 per 100 ml.

pH

In July and September 1964 there was a significant decrease in pH between the Millstone River and Cyanamid Dam. In July, pH declined from 8.2 to 7.3, and in September dropped from 8.5 to 7.4. This sudden change was not observed in August and October.

Color

During all four runs color at the confluence with the Millstone ranged from 15 to 30 units. Downstream from this point to mile point 18.9 there was a significant increase in color. At Station 18.9 color ranged from 100 to 250 units.

Water Quality Monitoring

During the period August 5 to September 3, 1964 an ORSANCO type electronic water quality monitor was in operation in the pool immediately upstream of the Fieldville Dam —— mile point 16.4. The monitor collected continuous data for dissolved oxygen, water temperature, turbidity, and oxidation reduction potential. During this same period eight-hour composite samples were collected on several occasions. Results of these analyses, together with average monitor readings for the periods indicated are presented in Table XVI. During this period of time BOD and phenol values more than doubled with maximum values of 42 mg/l and 162 ppb respectively. Dissolved oxygen readings declined to zero and oxidation reduction potential became negative. Septicity developed and extensive gas production was observed by Project staff.

Water quality conditions at the mouth of the Raritan River have been analyzed by an ORSANCO robot monitor, located at the Victory Bridge, Perth Amboy, N.J., since 1962. Monitoring results during 1964 confirmed upstream analyses described previously.

Maximum recorded dissolved oxygen at Perth Amboy was 13 mg/l, or 125% of saturation in April 1964. During the late summer and early fall of 1964 dissolved oxygen levels were reduced with a minimum observed value of 0.3 mg/l on September 16th. During this same period of time oxidation reduction potential was observed to have negative values for intermittent periods of two to three consecutive days, as compared to the normal range observed of up to 400 millivolts.

TABLE XVI

RARITAN RIVER WATER QUALITY DATA
FIELDVILLE DAM

Date	BOD mg/l	COD mg/l	Org N mg/l	Phenol ppb	DO* mg/l	Min ORP* mv	Temp.*
8/5/64	8	53	10.7	34	-	-	-
8/6/64	8	56	10.6	32	2.9	435	74
8/12/64	13	69	12.9	45	2.4	273	74
8/18/64	16	87	20.6	69	0.21	0	72
8/19/64	11	87	19.9	78	2.6	Neg.	74
8/28/64	18	111	19.7	50	0.09	Neg.	75
8/29/64	18	119	21.6	62	0.10	Neg.	75
9/2/64	-	176	34.3		0.08	Neg.	74
9/3/64	-	284	34.0		0.09	Neg.	74
9/8/64	36	247	37	125	0.15	-	72
9/9/64	42	234	36	162	0.15	-	73
9/10/64	37	196	37	120	0.14	-	73
9/11/64	37	175	30	121	0.12	-	73

*Data from ORSANCO robot monitor.

All other data based on average of three 8-hour composite samples.

WATER TEMP., RARITAN RIVER

JULY-OCT., 1964

DEPTH 2 FEET

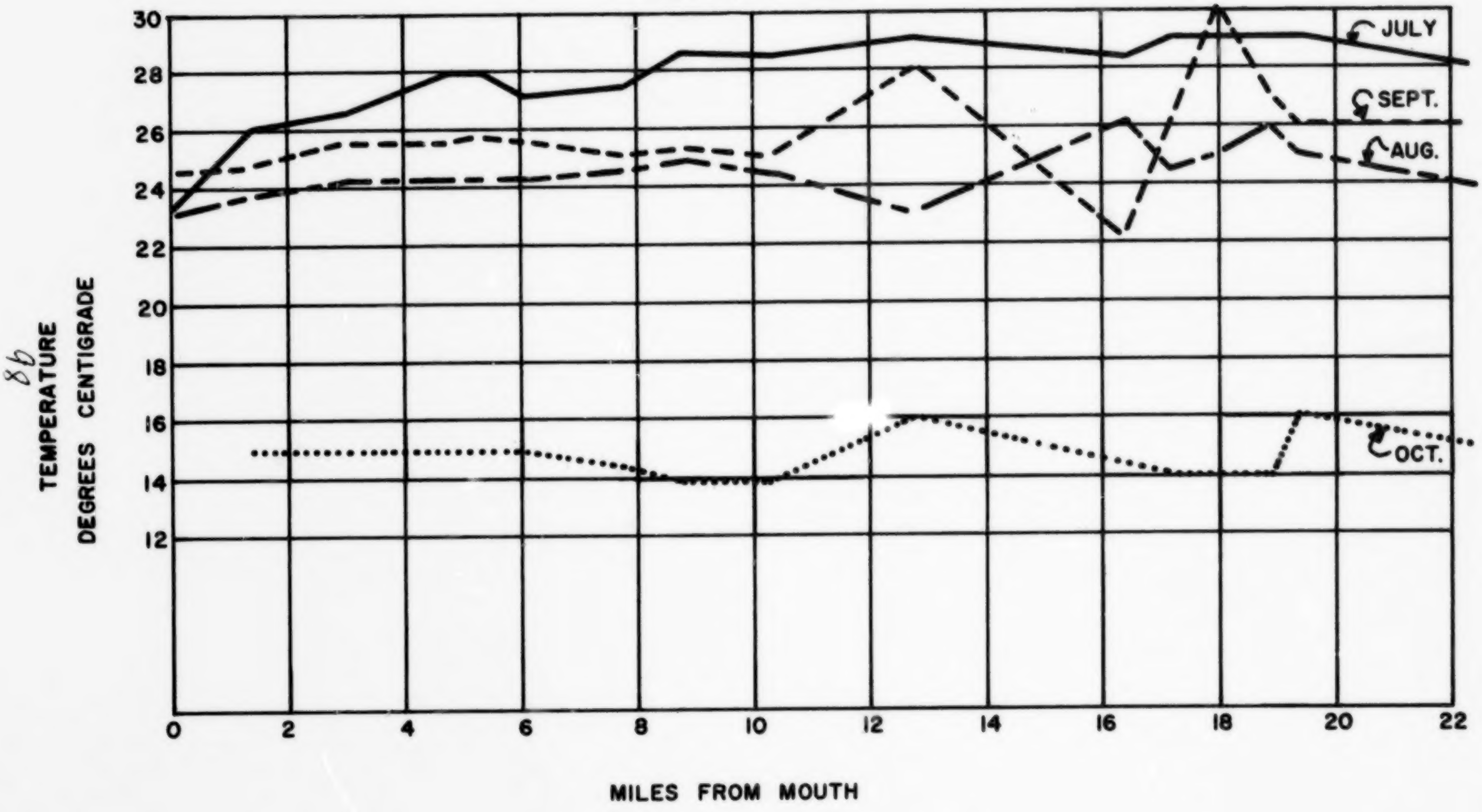


FIGURE 31

GPO 956-592

BIOCHEMICAL OXYGEN DEMAND
RARITAN RIVER
JULY-OCT., 1964

DEPTH 2 FEET

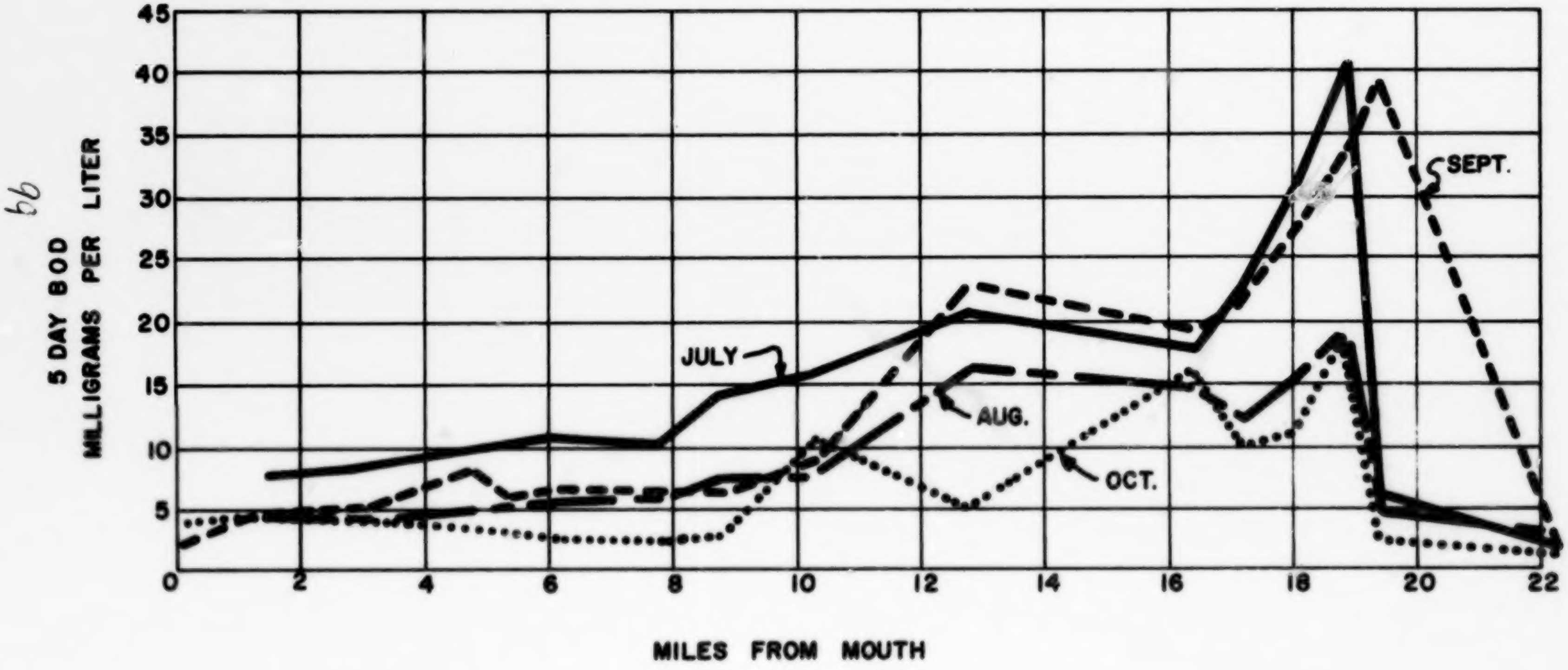


FIGURE 32

GPO 956-592

DISSOLVED OXYGEN
RARITAN RIVER
JULY-OCT., 1964
DEPTH 2 FEET

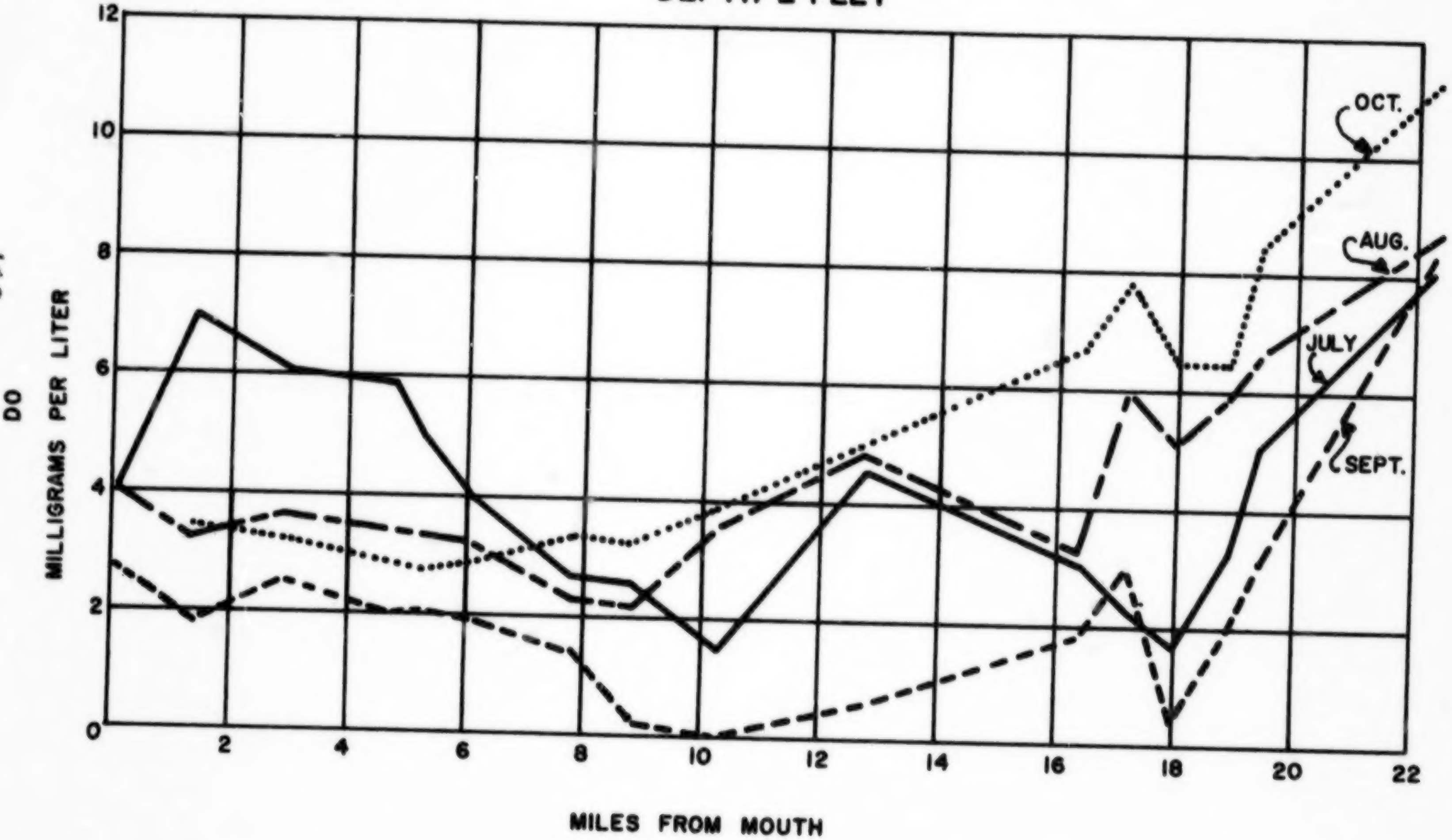


FIGURE 33

GPO 956-392

MPN COLIFORM, RARITAN RIVER

JULY-OCT., 1964

DEPTH 2 FEET

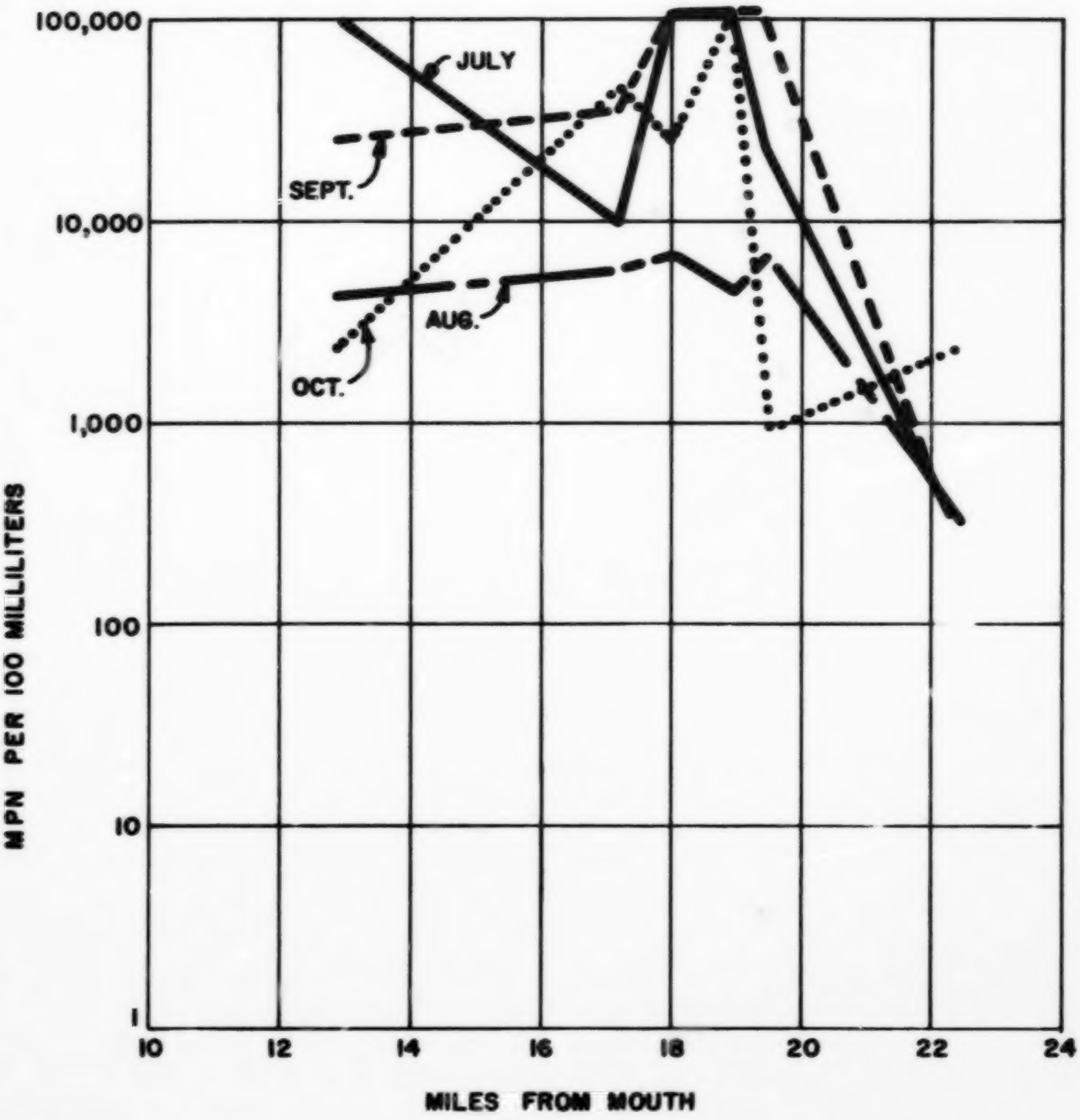


FIGURE 34

GPO 956-392

101

SPECIAL STUDIES

A number of special investigations were undertaken by the Project to provide further data on water pollution problems in the study area. Included were an examination of water movement and dispersion patterns within Raritan Bay; an evaluation of the effects on water quality of combined sewer overflows; mathematical analyses to explain the variations found in the chemical and bacteriological analysis of Bay water samples; a study of the relationship between chlorination of wastewater treatment plant effluents and bacteriological densities in Raritan Bay; determination of the bacteriological and chemical quality of shellfish taken from the Bay; and isolation of certain pathogenic bacteria from study area waters, sewage effluents and shellfish. Results of these special investigations are presented below.

Water Movement and Dispersion

Examination of the geographical structure of the study area suggests the hydraulic complexity of the system, due to interconnections between the bodies of water as well as other waters external to Raritan Bay and Arthur Kill. Any satisfactory pollution control program developed for Raritan Bay and Arthur Kill must be based on knowledge of the movement of waters between these various bodies so as to recognize probable paths of flow of pollutional materials. Accordingly, the Project conducted investigations of water movement by tracer dye studies, geological investigations, and by reviewing available hydraulic model data. Dye studies provided information on water movement and dispersion characteristics under conditions actually observed at the time of each dye release. The geological survey of Raritan Bay was conducted to obtain information on long term water movement and distribution of sediment throughout the Bay. Previously reported studies by the U.S. Army Corps of Engineers on the Vicksburg model of New York Harbor were reviewed to obtain further information on the interrelationship between the various bodies of water involved in the Raritan Bay Project study area.

Dye release studies were made in the Raritan River, Arthur Kill, westerly portion of Raritan Bay and in Upper Bay to observe the interrelationship of these waters. Rhodamine B dye, used in all studies conducted by the Project, was added to the water as an instantaneous release. In all studies, except upper Raritan River, resulting movement of dye was monitored visually and by the use of Turner fluorometers for as long as deemed advisable. During the monitoring phase, boats equipped with fluorometers and continuously recording Rustrak meters cruised the dye mass to determine its movement, location of the limits, and the peak concentrations. Monitoring boats proceeded on a predetermined course —— established between known navigational aids —— at a fixed rate of speed. In addition to recording dye concentration, records were also maintained on time and boat course so as to permit proper correlation between an observed dye concentration and the exact location and time of such reading.

The Raritan River dye study of April 1964 was limited to a simple measurement of time between release and the appearance of dye at a downstream location.

On August 15, 1962 dye was released at high water slack in the western end of Raritan Bay near the Ward Point secondary channel. Dispersion of the dye was monitored over a period of four days. Dye moved as a fairly well defined mass, with the outer limits readily discernible during the first day. During the second and third days, dye became progressively more diffused and was distributed laterally, longitudinally, and vertically throughout the inner Bay. At the end of this three day period dye was still detectable at the following locations:

(1) Raritan River at Victory Bridge

(2) Arthur Kill at Tufts Point

(3) Raritan Bay at Seguine Point, Staten Island, N.Y.

(4) Raritan Bay off Keyport, N.J.

The outline of the dye mass five tidal cycles after release is shown in Figure 35. After the five tidal cycles peaking was still discernible just east of the original dye release area. The net movement of the dye mass had been approximately ½ mile seaward over the five tidal cycles, suggesting a net seaward movement of the dye at a rate of approximately one-tenth mile per tidal cycle.

On October 17, 1962, at low water slack, dye was released in the Arthur Kill just below Outerbridge Crossing. Release was timed to enable observation of the seaward movement of the dye under the most adverse conditions of current movement. Under low water slack conditions dye must first transit upstream with the incoming current; then reverse at the turn of tide and run downstream out from the Kill. Monitoring was carried out for four days. Dye dispersed throughout the entire Kill area as far north as Goethals Bridge. At the end of four days, dye was dispersed uniformly throughout the entire western end of Raritan Bay, in the same areas and in approximately the same concentrations that were found after the August 1962 dye release in the Bay. The peak of the dye concentration after four days was located in the deep water anchorage southeast of Perth Amboy, N.J. The net seaward movement of the dye mass was approximately nine miles in a period of eight tidal cycles, or approximately one mile per tidal cycle. This study indicated that material introduced into the Arthur Kill near the Outerbridge Crossing at low slack tide would:

(1) affect a stretch 10,000 yards to the north in six hours;

(2) affect the western end of Raritan Bay within 12 hours;

(3) affect the entire Arthur Kill within 30 hours, and Newark Bay within 54 hours;

(4) affect Raritan Bay on a line from Seguine Point, Staten Island, N.Y., to Keyport, N.J., within 48 hours.

Diffusion coefficients in the Arthur Kill were found to be 0.1 to 2.7 square miles per tidal cycle. Results of this dye study are shown in Figure 36.

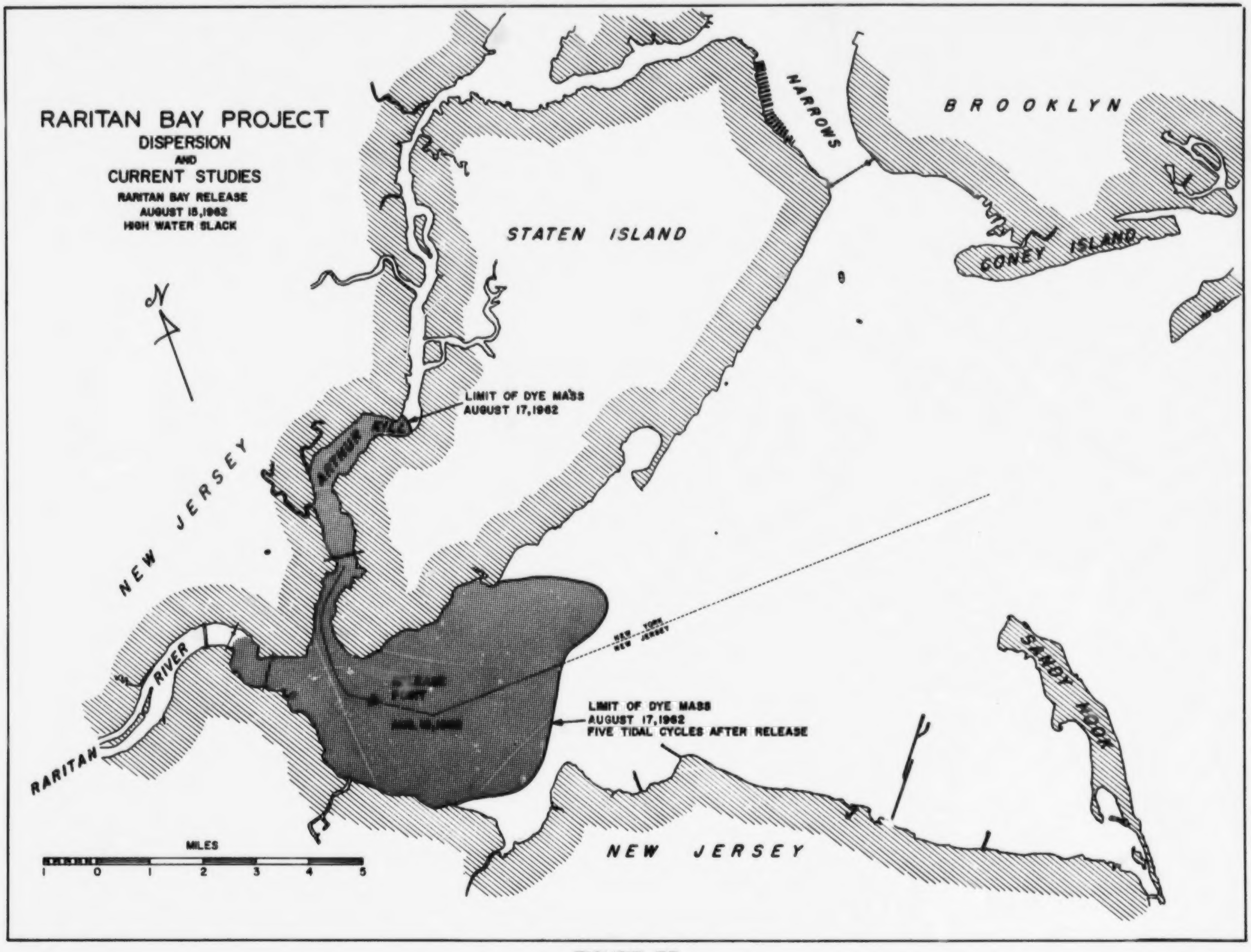

RARITAN BAY PROJECT
DISPERSION
AND
CURRENT STUDIES
RARITAN BAY RELEASE
AUGUST 15,1962
HIGH WATER SLACK
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
LIMIT OF DYE MASS
AUGUST 17,1962
ARTHUR KILL
NEW JERSEY
NEW YORK
NEW JERSEY
RARITAN RIVER
LIMIT OF DYE MASS
AUGUST 17,1962
FIVE TIDAL CYCLES AFTER RELEASE
SANDY HOOK
NEW JERSEY
MILES
1
0
1
2
3
4
5

FIGURE 35

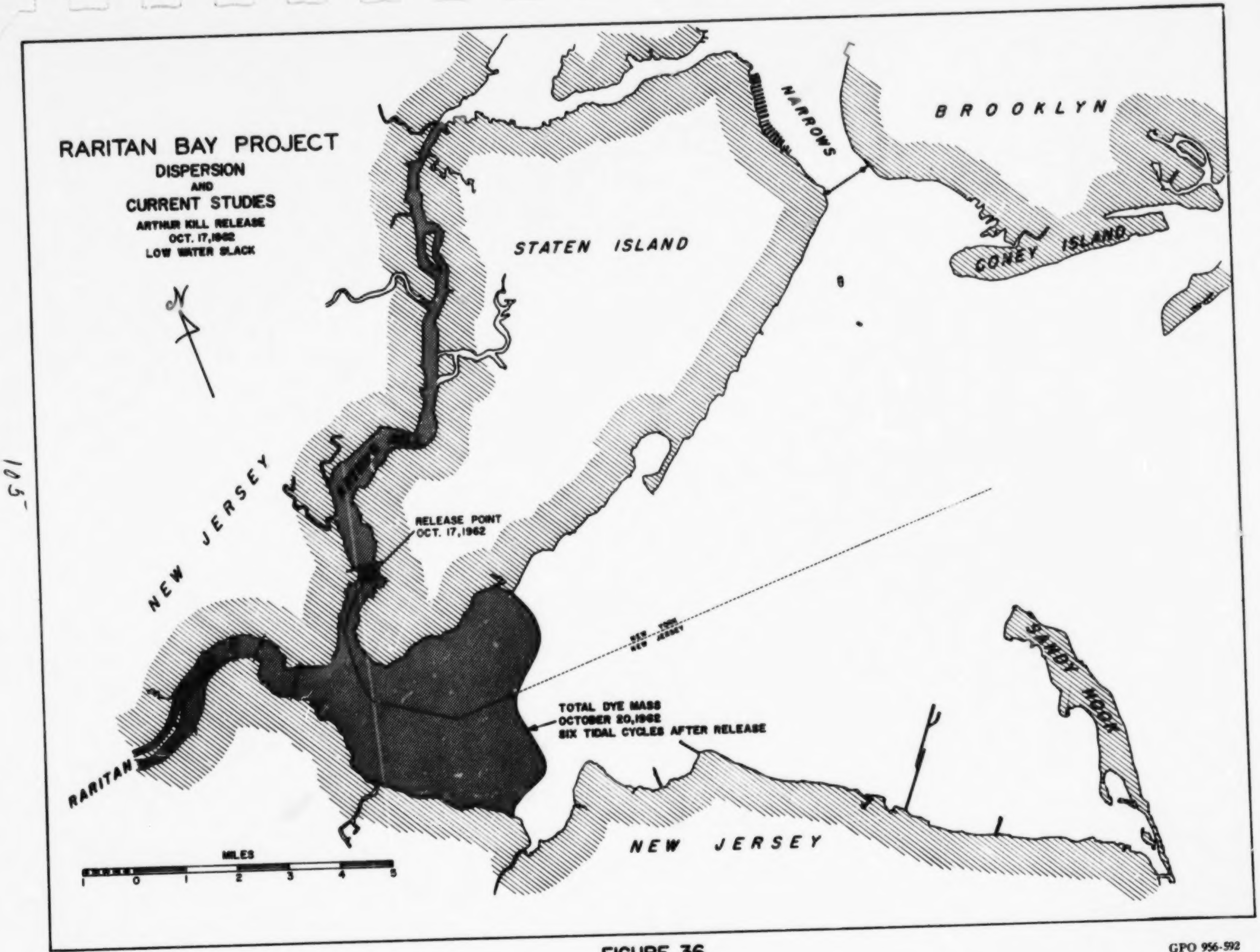

RARITAN BAY PROJECT
DISPERSION
AND
CURRENT STUDIES
ARTHUR KILL RELEASE
OCT. 17,1962
LOW WATER SLACK
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
NEW JERSEY
RELEASE POINT
OCT. 17,1962
NEW YORK
NEW JERSEY
TOTAL DYE MASS
OCTOBER 20,1962
SIX TIDAL CYCLES AFTER RELEASE
SANDY HOOK
RARITAN
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 36

GPO 956-592

On April 14, 1964 dye was released at high water slack at New Brunswick, N.J., on the Raritan River. Dye was monitored for five days throughout the 13 mile navigable reach of the River, the five mile navigable reach of South River and Washington Canal, and the western end of Raritan Bay. Results of this study showed that:

(1) material introduced at New Brunswick affects the River downstream to the Washington Canal entrance within six hours;

(2) such material can affect the western portion of Raritan Bay within 18 hours;

(3) on entering Raritan Bay the dye followed two paths, one along the navigation channel to the north and east, the second along the New Jersey shore line to the south;

(4) such a release had little effect upon the Arthur Kill.

On June 30, 1964 a dye release was made at Fieldville Dam on the Raritan River, five miles upstream of New Brunswick, N.J. This study indicated a time of passage from the dam to New Brunswick of at least 14 hours.

On September 16, 1964 dye —— 1,000 pounds —— was released at high water slack over the Passaic Valley Sewage Treatment Plant outfall near Robbins Reef in Upper Bay. This point is located on the western edge of the Bay channel about 700 yards north of the Kill Van Kull. This dye release showed the following results:

(1) material introduced in the northwest sector of the Upper Bay affects a broad area of Lower Bay, and is found on the Staten Island shore from Midland Beach to the Narrows within six hours of release;

(2) within 32 hours of release such material affects a large area of Raritan Bay, and is found on the Staten Island shore from the Narrows to Great Kills, as well as on the Coney Island shore of Brooklyn;

(3) on an ebb current there was little lateral mixing across the Narrows, but lateral mixing does occur on the first flood current following release;

(4) material moving from the release point on the first ebb passes along the western edge of the channel and the Staten Island shore before passing through the Narrows.

The limits of the dye mass at various stages of time following release are shown in Figure 37.

A geological investigation of Raritan Bay was made to obtain information on long term water movement and sediment distribution. Details on this study and its results are contained in the Appendices to this report. In summary, the investigation found, based upon the sediment distribution within the Bay, that:

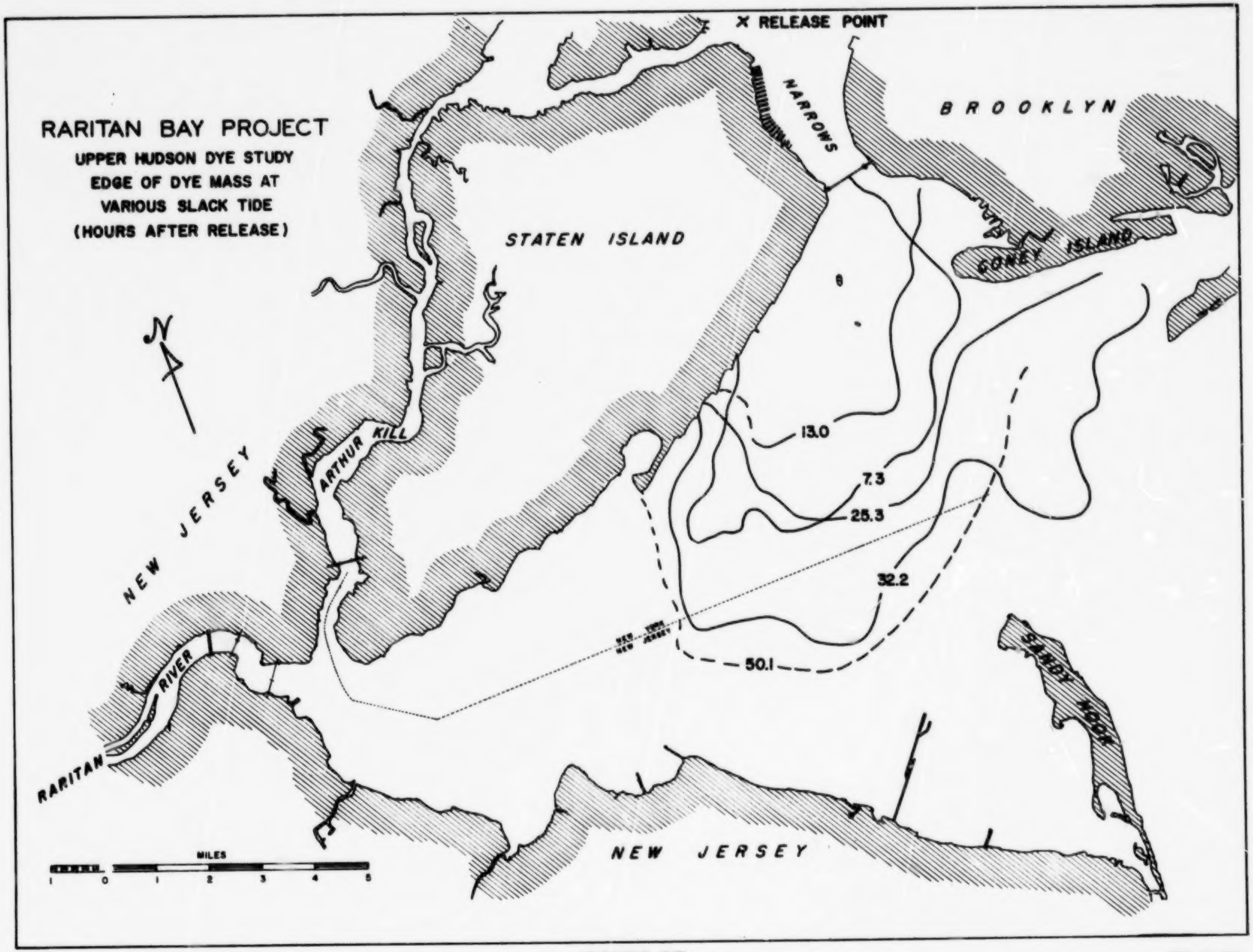
(1) fresh water inflow from the Raritan River moves along the southern section of the Bay towards Sandy Hook; and

(2) particles introduced into the Bay at widely varying locales were eventually transported throughout the Bay with the finer particles gravitating toward the area bounded by Seguine Point and Great Kills, Staten Island, N.Y., and Keyport and Keansburg, N.J.

Project studies, as well as those performed by the U.S. Army Corps of Engineers on the Vicksburg model of New York Harbor, which have been previously reported by other agencies, indicate the complexity of the Raritan Bay system. Essentially the waters of Raritan Bay may be affected by materials discharged into waters outside the immediate limits of the study area. Hence, any effective control program for pollution control in Raritan Bay must consider the Bay not as an independent estuary, but as part of a larger interconnected system which includes Upper Bay, Kill Van Kull, Newark Bay, Arthur Kill and the Raritan River.

Effects of Combined Sewer Overflows

Within the metropolitan New York area there are a number of combined sewer systems. During normal dry weather periods wastes conveyed by these sewers receive treatment if facilities exist. During periods of heavy rainfall, when these sewers must carry both wastes and stormwater, bypassing of treatment facilities via regulating chambers or overflows is necessary. The Project attempted to evaluate the effects on bacteriological water quality resulting from the overflow of such discharges during periods of heavy rainfall. Two systems, that of Perth Amboy, N.J., and Brooklyn, N.Y.,



RARITAN BAY PROJECT
UPPER HUDSON DYE STUDY
EDGE OF DYE MASS AT
VARIOUS SLACK TIDE
(HOURS AFTER RELEASE)

X RELEASE POINT
NARROWS
BROOKLYN
CONEY ISLAND
STATEN ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
NEW YORK
NEW JERSEY
N
13.0
7.3
25.3
32.2
50.1
MILES
1 0 1 2 3 4 5

FIGURE 37

GPO 956-592

were selected for analysis. Sampling stations 33, 34 and 62, at the confluence of the Raritan River and Arthur Kill were selected as being indicative of water quality in the vicinity of the Perth Amboy combined sewer system, and readily affected by overflows from that system. Station 102 in the Narrows was similarly selected as being indicative of the effects of discharge by stormwater overflows from the Brooklyn area. Bacteriological data collected by the Project for the period July 1962 through September 1963 were utilized for Stations 33 and 34, and data from January 1963 through September 1963 were used for Stations 102 and 62. Rainfall information for the study period was obtained from published records of the U.S. Weather Bureau. The station at Rahway, N.J., was selected as the nearest location to Perth Amboy and the station at Avenue V, Brooklyn, N.Y., was used for the Narrows. Several analyses described below were made of these data to determine if any correlation could be found between rainfall and high bacterial densities in the receiving waters.

Graphs were prepared with total coliform and fecal streptococcus counts, as well as daily rainfall plotted on the ordinate and date on the abscissa. The resulting display of variations in bacteriological density and rainfall for each station was examined visually, however there was no apparent correlation. Coliform and fecal streptococcus data for each station were next separated into those data collected at ebb tide and those collected at flood. Two graphs were then plotted for each station, as above, using only ebb tide data for one and flood data for the second. Again visual examination of these graphs showed no apparent correlation.

Bacteriological data were then separated into four groups: Collected within 24 hours of rainfall; within 48 hours of rainfall; within 72 hours of rainfall; and that collected with no rainfall for 72 hours prior to collection. Scatter diagrams were made with the classification by above groups as the independent variable and the bacteriological data as the dependent variable. No relationship was apparent with this approach.

All bacteriological data which had been collected with rainfall appearing up to three days prior to collection were then listed. Individual graphs were made with hourly rainfall and bacteriological counts as the ordinate and time as the abscissa. Areas under the hourly rainfall graph were then calculated for periods of 24, 48 and 72 hours. Secondary graphs were then made with the area from the rainfall curve as the independent variable and bacterial counts densities as the dependent variable. Again no relationship was found.

The techniques used suggest no apparent correlation between rainfall and high bacteria counts; however it cannot be concluded that stormwater overflows have no effect on water quality in Raritan Bay. The data available were not specifically collected for such analysis; more important, the raw sewage discharges into the areas of the Bay considered would undoubtedly mask any effects by stormwater overflows. Once the discharge of raw sewage is discontinued, and all treated wastes discharges receive adequate chlorination, such stormwater overflows may constitute a serious pollution problem. However, at present the problem of stormwater overflows cannot be defined, as any effects are so obscured by poor water quality attributable to other factors.

Mathematical Analysis of Sampling Variation

In order to validate the sampling program adopted by the Project, provide an estimate of the most representative parameter values, and serve as a guide for future sampling programs, analytical data were subjected to a time series analysis. The analysis served to develop predictable time dependent components of observed variations in parameter values.

To determine cyclical components of a time series, available data should be distributed in time over the periods to be determined. Three sampling procedures used by the Project yielded data distributions suitable for time series analysis. These were:

(1) Simultaneous sampling of Bay, shoreline and wastewater treatment plant effluent stations on a weekly interval over a one-year period;

(2) sampling of selected Bay stations on an hourly interval over a 24-hour period; and

(3) continuous automatic sampling on a 30-minute interval by an electronic monitor located at Victory Bridge at the mouth of the Raritan River.

Weekly samples were taken at a grid of locations in the Bay, along the shoreline, and at eight sewage treatment plant effluents during the 56 week period from August 1962 through September 1963. Initially, in the Bay stations, only those numbered 1 through 34 were sampled. Effective February 13, 1963, additional stations were established and some of the original stations were discontinued to permit a better description of the pollution gradients. Only 31 of the 50 weekly stations were sampled over a full year and used for this analysis because of this change. Parameters selected for the time series were air temperature, sample temperature, dissolved oxygen, chloride, MF fecal streptococcus, MPN confirmed coliform, and MPN fecal coliform. Stations were sampled at nearly the same time each week, since a preset course and consistent starting time were followed. On occasion, due to inclement weather, it was necessary to delay the sampling one day or to completely omit a week; however, the maximum number of consecutive weeks of missing data for any parameter was three.

Samples taken on the same day of the week and hour of the day for one year would be uniformly distributed over an annual cycle. However, the 12.42 hour tidal period is such that there would be a 0.526 cycle interval between individual weeks and a 0.053 cycle interval every two weeks. Therefore, after one year of sampling while analytical values would be distributed over the entire tidal cycle, the 0.526 weekly and 0.053 biweekly cycle intervals would generate respectively what would appear to be a two-week and 19 week period. Any 24-hour or seven-day cyclic variation present would not be measured by this sampling procedure, but would bias the mean by as much as ± the amplitude of the variation.

A least squares regression analysis was performed on the weekly interval data so as to fit a base value, linear trend, and annual and tidal cycles. This analysis has the advantage over other procedures of using actual sampling times, which need not be equally spaced, and makes possible estimates of high frequency components. The final form of the equation developed for this regression is as follows:

$$\text{Parameter} = M + At + B\cos(w_1t - \phi_1) + C\cos(w_2t - \phi_2)$$ where

M = Base value

A = Slope of linear trend

B = Amplitude of annual component

C = Amp. of tidal comp.

ϕ_1 = Lag of annual comp.

ϕ_2 = Lag of tidal comp.

t = Time from time zero*

w = Angular frequency with time = $\frac{2\pi}{\text{period}}$

*Time zero was established as low water slack on August 6, 1962. The four components of this equation, i.e., base value, trend, tidal and annual, cannot describe completely all of the parameter variation. The remaining variation, referred to as the unexplained component, was defined as the standard error of the estimate and calculated as:

$$U = \sqrt{\frac{\Sigma (P_o - P_c)^2}{6}}$$

where P_o = observed value

P_c = calculated value

U = Unexplained term

The base value obtained from the regression is a good estimate of the true parameter mean value. It is not biased by the sampling distributions over the periods of variation such as the tidal or seasonal cycles, as the commonly computed mean could be. The base value may be biased, however, by a non-cyclic trend or by sampling at same point on a cycle as was done for the 24-hour and seven-day cycles.

The trend coefficient is for a purely linear term. In reality it may be part of either a cyclic period longer than one year or a non-linear, non-cyclic term. Since it is impossible to determine which of these is the case with the information available, the trend should be viewed only as a means of estimating the magnitude of variations measured in years, and no significance should be given to the sign.

The unexplained variation term contains all variation caused by:

(1) non-linearity of the trend;

(2) cyclic terms, other than annual or tidal;

(3) random causes (non-cyclic), such as analytical error, slug releases and unusual weather.

Figure 38 presents graphically dissolved oxygen results of the regression for Station 34S. During any given day the DO would be expected to vary within the limits shown by the two solid line curves and average the value on the dashed line curve. Within this day it is possible to estimate the DO within ± 1.56 mg/l.

The coefficients of the annual and tidal components, the unexplained term, and 182.5 times the trend coefficient were ranked by magnitude. This is the ranking of expected value variation or range during a one year period. Table XVII gives the most predominant component for the maximum to minimum variation, the number of stations having the indicated component and rank, and the average value of the component when all stations are appropriately grouped into Bay, New Jersey shore, Staten Island shore, or wastewater treatment plant stations. Table XVIII gives the base value and expected range of the parameters over one year.

After subtracting the regression estimate from the observed parameter value, the remainder was subjected to spectral analysis to determine what cycles, other than annual, tidal, and long term, influenced the data. Ten lags were computed, representing periods of ∞, 140, 70, 46, 35, 28, 23, 20, 17, 16 and 14 days. Results are presented in Table XIX which shows those periods found to be significant in the remaining variation.

The 70 day period, which actually represents all periods from 46 to 140 days, may be the 133 day cycle generated by the sampling schedule. The 140 day period may be caused by the same generated cycle. The 28 day, however, is probably a true cycle, the lunar tidal component.

REGRESSION ANALYSIS
AUG. 1962 - JULY 1963
STATION 34S

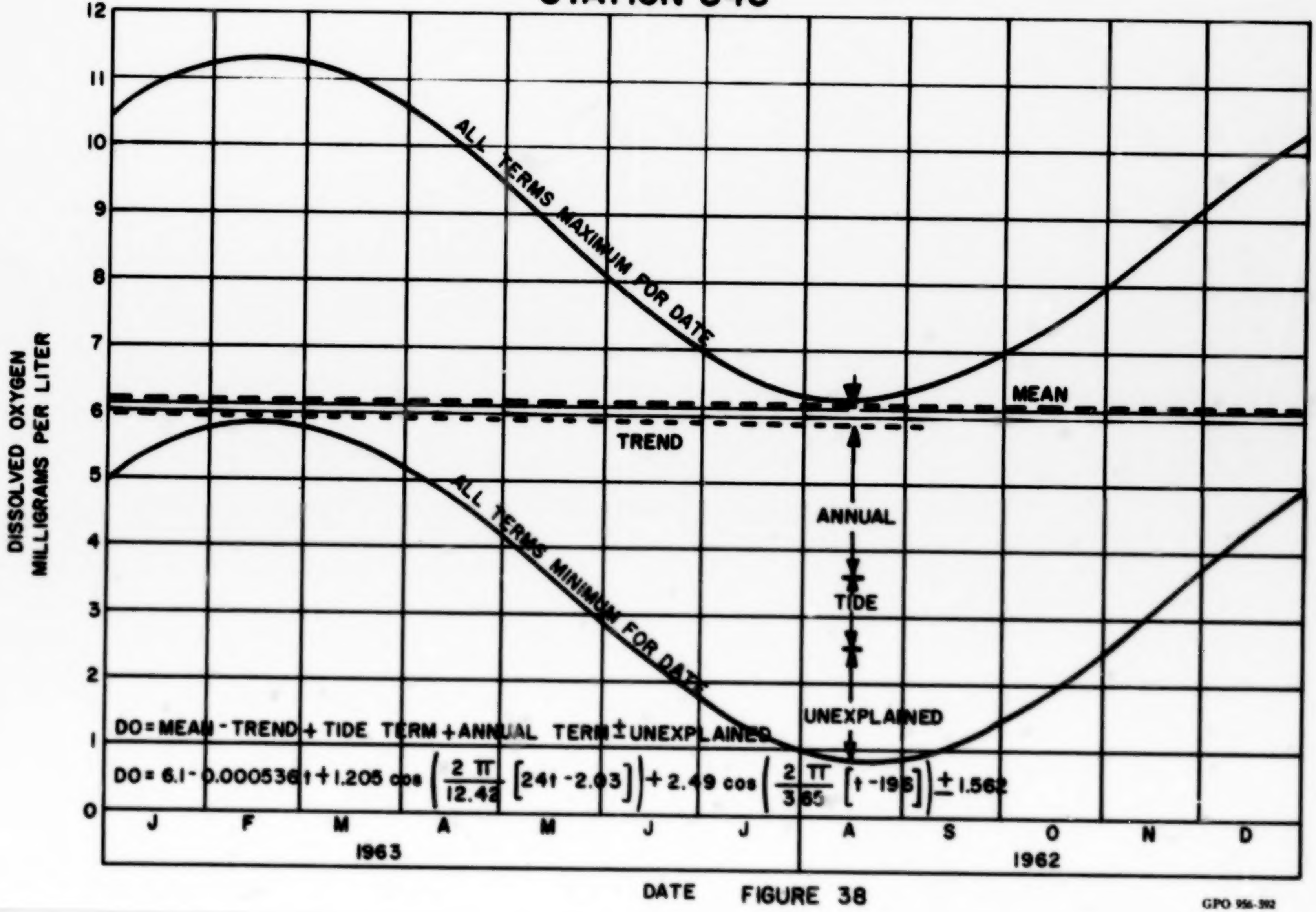


FIGURE 38

GPO 956-392

TABLE XVII

SUMMARY OF VARIATION FROM REGRESSION ANALYSIS

Parameter	Predominate Component Producing Max to Min Variation				No. of Stations Having Predominate Comp. & Variation Rank				Average Value of Component				
									L	A	T	U	Base
					Bay Stations (44) Grouped								
Air Temp. °C	A	U	L	T	44	44	32	32	1.38	12.71	0.761	3.39	12.39
Sample Temp. °C	A	U	L	T	44	44	31	31	0.63	11.31	0.39	1.35	12.4
D.O. mg/l	A	U	T	L	42	41	29	30	0.444	2.426	0.592	1.381	7.70
MF Strep[1/]	U	A	T	L	31	26	28	36	0.264	0.933	0.657	1.233	4.05
MPN Coli[1/]	U	T	A	L	35	24	31	37	0.318	0.628	0.932	1.251	6.551
MPN Fecal C.[1/]	U	A	A* T	L	35	16	18	32	0.333	0.706	0.926	1.386	5.430
Chlorides mg/l	U	A	L	T	32	24	24	22	412	873	441	1057	13,312

[1/] Expressed as natural log (loge) of density per 100 ml.
* = Tied Rank
L = Long term trend (182.5 x Trend Coef.)
A = Annual period cycle (Annual Coef.)
T = Tidal period cycle (Tide Coef.)
U = Unexplained variation

TABLE XVII (Cont.)

SUMMARY OF VARIATION FROM REGRESSION ANALYSIS

Parameter	Predominate Component Producing Max to Min Variation				No. of Stations Having Predominate Comp. & Variation Rank				Average Value of Component L	A	T	U	Base
Staten Island Shore Stations (16) Grouped													
MF Strep	U	A	L	T	12	12	10	10	0.510	1.240	0.430	1.703	4.004
MPN C Coli	U	A	T	L	15	10	8	10	0.395	0.736	0.514	1.350	6.392
MPN Fecal C.	U	A	T	L	13	7	7	10	0.468	0.983	0.650	1.426	5.766
New Jersey Shore Stations (16) Grouped													
MF Strep	U	A	T	L	15	12	8	9	0.500	1.053	0.435	1.754	4.012
MPN C Coli	U	A T	L	L	16	8 8	8	8	0.372	0.607	0.565	1.461	5.501
MPN Fecal C.	U	A	A	T	15	6	10	10	0.627	0.758	0.567	1.726	4.178
Sewage Treatment Plants (8) Grouped													
MF Strep	U	A	$\frac{A}{T}$	$\frac{L}{T}$	7	4	3	4	0.827	0.951	0.499	1.823	4.389
MPN C C	U	A	A	$\frac{L}{T}$	6	4	4	4	0.900	1.475	0.685	2.466	4.849
MPN F C	U	L	A	T	7	4	5	1	0.925	0.768	0.549	2.026	3.019
BOD	U	A	T	L	6	4	4	5	11.47	21.98	14.78	45.89	145.12

TABLE XVIII

BASE AND EXPECTED RANGE VALUES OF SELECTED PARAMETERS

Parameter	Base Value	Expected Range Min	Expected Range Max
	Bay Stations		
Air Temp., °C	12.40	-5.84	30.64
Sample Temp., °C	12.4	-1.28	26.08
DO, mg/l	7.70	2.86	12.54
*MF Strep	54	3	1,260
*MPN Coli	700	30	16,000
*MPN Fec Coli	230	8	6,500
Cl^-, mg/l	13,312	10,529	16,095
	New Jersey Shore Stations		
*MF Strep	55	1	2,300
*MPN Coli	240	12	5,000
*MPN Fec Coli	65	2	2,600
	Staten Island Shore Stations		
*MF Strep	55	1	2,600
*MPN Coli	600	30	12,000
*MPN Fec Coli	320	9	11,000
	Sewage Treatment Plant Effluents		
*MF Strep	81	1	4,800
*MPN Coli	126	1	30,200
*MPN Fec Coli	20	1	1,400
BOD, mg/l	145.12	51.00	239.24

*Expressed as density per 100 ml.

TABLE XIX

SIGNIFICANT CYCLES BY SPECTRAL ANALYSIS

Station	Chloride		D.O.		MF Strep		MPN Coli	
	Period, Days	% of Variation	Period, Days	% of Variation	Period, Days	% of Variation	Period, Days	% of Variation
7S	140	-	140	50	None	-	70	32
11S	70	41	28	42	None	-	None	-
13S	70	50	70	42	None	-	None	-
26S	70	52	None	-	None	-	None	-
34S	70	42	70	40	None	-	None	-
463S	70	37	70	44	None	-	70	48

Since the preceding analyses were based upon weekly samplings, no estimate could be made of the variations due to a 24-hour cycle. To estimate the magnitude of this component, data obtained from a 24-hour sampling operation were used. On June 27 and 28, 1963 samples were collected over a period of 24 hours at Stations 34 and 26, and at the dock of the Public Health Service Quarantine Station at the Narrows, Staten Island, N.Y. Hourly determinations were made of salinity, water temperature, dissolved oxygen, MPN confirmed coliform and MPN fecal coliform. Fecal coliform and fecal streptococcus analysis by membrane filters were made at 30-minute intervals.

A Fourier Series analysis was performed on the data for periods of 24 and 12 hours, the daily and tidal cycles. Since the regression equation included the tidal cycle, a comparison of the tidal cycle calculated by both regression and Fourier Series serves to validate the use of the daily cycle found by the Fourier Series. Results of the Fourier Series analysis, and a comparison of the tidal component with that found by the regression equation are presented in Table XX

Chlorination of Sewage Treatment Plant Effluents

In 1963 a cooperative study was undertaken by the Project and New Jersey State Health Department to determine the effect of post-chlorination of primary treatment plant effluents on water quality of the westerly portion of Raritan Bay. Following the establishment of base line conditions by bacteriological analyses of the Bay waters, effluent chlorination at nine plants discharging an average total of 59 MGD into the western area of Raritan Bay was halted simultaneously for a period of nine days and then resumed. Data collected during this study showed a significant increase in the bacterial population present in the Bay following cessation of post-chlorination. Within six to 50 hours after cessation of chlorination, depending on station location, the bacterial population in the Bay reached new stable levels significantly higher than those found during the base line study. Following resumption of post-chlorination there was a significant reduction in the bacterial population at most of the stations. Salmonella organisms were isolated from samples of unchlorinated plant effluent and from the waters receiving these discharges. The study concluded that post-chlorination of wastewater treatment plant effluent was an effective measure for reducing the total bacterial population and the occurrence of Salmonella in the waters of western Raritan Bay.

Shellfish Quality

Between August 1963 and August 1964 the Project conducted bacteriological analyses on 391 shellfish samples taken from 50 stations throughout Raritan Bay. Analyses were performed for MPN total coliform, MPN fecal coliform, and for the presence of Salmonella bacteria. The results are summarized in Table XXI

Samples from 12 of the 50 stations had geometric mean total coliform densities greater than 2,400 per 100 grams. The geometric mean fecal coliform density in shellfish taken from these same 12 stations ranged from 610 to 16,000 per 100 grams. The presence of high total coliform densities appeared to show some correlation with water temperature. None of the shellfish taken from waters with temperatures less than 8.5°C had total coliform MPNs of 2,400 or more per 100 grams. The 12 stations having geometric mean coliform densities greater than 2,400 per 100 grams were located in the northerly sector of the Bay in an area extending generally south of Staten Island to and

TABLE XX

DAILY AND TIDAL COMPONENTS OF VARIATION BY FOURIER SERIES

	Daily (24-hr) Cycle		Tidal Cycle			
Station & Parameter	% of Variance	D_f	% of Variance	C_f	C_r 1/	$\frac{D_f}{C_f}$
26S						
D.O., mg/l	3.4	0.58	4.7	0.68	0.90	0.8
MF Strep*	31.1	0.94	3.6	0.32	0.31	2.94
MPN Coli*	6.4	0.49	48.2	1.36	1.60	0.36
MPN Fecal Coli*	20.5	0.85	52.8	1.37	1.83	0.62
Salinity, °/oo	32.4	0.07	20.0	0.05	-	1.28
34S						
D.O., mg/l	54.4	1.50	38.1	1.30	1.21	1.15
MF Strep*	66.6	1.74	19.1	0.94	1.12	1.85
MPN Coli*	62.3	1.62	4.3	0.43	0.96	3.77
MPN Fecal Coli*	51.5	1.45	10.7	0.66	1.17	2.20
Salinity, °/oo	3.3	0.01	41.0	0.05	-	0.27
Quarantine Dock						
D.O., mg/l	29.8	0.70	61.9	1.01	-	0.69
MF Strep*	57.4	1.38	13.4	0.67	-	2.06
MPN Coli*	5.2	0.28	30.2	0.68	-	0.41
MPN Fecal Coli*	11.5	0.48	58.8	1.08	-	0.44
Salinity, °/oo	1.6	0.02	81.1	0.12	-	0.17

1/ Coefficient of tidal variation as calculated by regression analysis.

*C_f, C_r & D_f expressed as natural log of density per 100 ml.

TABLE XXI

RESULTS OF BACTERIOLOGICAL EXAMINATION OF SHELLFISH MEATS

	Total Coliform, MPN/100g.				Fecal Coliform, MPN/100g.				Salmonella Isolations	
Station	No.	Min	Max	Geom Mean	No.	Min	Max	Geom Mean	No.	Serotypes
1	8	< 20	490	180	8	< 20	330	120		
2	8	< 20	1,700	550	8	< 20	460	140		
3	8	< 20	2,300	700	8	< 20	2,300	370		
4	9	< 20	24,000	3,200	9	< 20	7,900	970		
6	7	< 20	17,000	5,700	7	< 20	13,000	3,100	4	S.st. paul; S.anatum; S.montevideo; S.litchfield
7	8	< 20	160,000	39,000	8	< 20	92,000	16,000	2	S.oranienburg; S.derby
10	7	< 20	35,000	8,700	7	< 20	11,000	2,600	2	S.derby; S.infantis
13	6	< 20	7,900	1,400	6	< 20	2,300	410		
14	8	< 20	330	100	8	< 20	130	45		
15	8	< 20	330	120	8	< 20	20	20		
16	8	< 20	330	120	8	< 20	230	52		
17	9	< 20	2,300	580	9	< 20	790	210		
18	7	< 20	4,900	1,600	7	< 20	1,300	350		
20	7	< 20	13,000	4,000	7	< 20	2,300	1,100		
21	6	< 20	13,000	4,900	6	< 20	3,300	1,300	1	S.derby
22	8	< 20	3,300	1,200	8	< 20	3,300	740	1	S.derby
23	8	< 20	7,000	1,400	8	< 20	790	260		
24	8	< 20	4,900	1,300	8	< 20	1,300	280		
25	9	< 20	35,000	5,700	9	< 20	3,300	1,000	1	S.tennessee
26	9	< 20	16,000	2,800	9	< 20	3,500	610		
27	8	< 20	3,300	1,000	8	< 20	2,200	620		
28	8	< 20	1,300	600	8	< 20	490	160	1	S.derby
29	7	< 20	790	260	7	< 20	490	110		
30	7	< 20	460	200	7	< 20	170	71		
31	8	< 20	460	210	8	< 20	230	95		
32	8	< 20	7,900	1,400	8	< 20	950	320		
33	7	< 20	2,300	930	7	< 20	790	350		
36	8	< 20	92,000	13,600	8	< 20	35,000	4,700	1	S.derby

TABLE XXI (Cont.)

RESULTS OF BACTERIOLOGICAL EXAMINATION OF SHELLFISH MEATS

	Total Coliform, MPN/100g.				Fecal Coliform, MPN/100g.				Salmonella Isolations	
Station	No.	Min	Max	Geom Mean	No.	Min	Max	Geom Mean	No.	Serotypes
37	7	< 20	24,000	6,600	7	< 20	4,900	1,700	1	S.anatum
39	9	< 20	24,000	5,200	9	< 20	24,000	3,500	1	S.6,7:K mono.
40	8	< 20	22,000	5,600	9	< 20	7,900	2,100	3	S.derby; S.anatum; S.6,7 non.mot.
41	9	< 20	3,300	1,100	9	< 20	490	150		
42	8	< 20	3,500	540	8	< 20	310	70		
43	7	< 20	490	150	7	< 20	140	67		
44	8	< 20	2,300	630	8	< 20	230	77		
45	7	< 20	490	190	7	< 20	140	52	1	S.typhimurium
46	8	< 20	230	97	8	< 20	80	31		
47	8	< 20	1,300	350	8	< 20	230	76	2	S.6,7:mon.mot; S.6,7:K mono.
48	8	< 20	3,300	780	8	< 20	790	150		
49	8	< 20	13,000	2,000	8	< 20	1,300	300		
50	8	< 20	3,300	600	8	< 20	490	92		
51	7	< 20	2,300	400	7	< 20	2,300	340		
52	7	< 20	4,900	860	7	< 20	460	110		
53	8	< 20	2,100	380	8	< 20	130	37		
54	7	< 20	7,900	1,300	7	< 20	490	90		
56	7	< 20	490	180	7	< 20	170	44	2	S.infantis; S.muenchen
57	8	< 20	4,900	820	8	< 20	490	160		
58	6	< 20	3,300	1,200	6	< 20	230	120		
61	6	110	7,000	1,400	6	< 20	4,600	820		
73	6	< 20	2,300	400	6	< 20	170	45		

across the New York-New Jersey state line.

Salmonella were isolated from clam meats collected at 14 of the 50 sampling stations. Of these 14 stations, nine also showed geometric mean total coliform densities greater than 2,400 per 100 grams of clam meat. The geometric mean coliform density in shellfish from the other five stations ranged from 180 to 1,200 per 100 grams. A total of 23 Salmonella isolations were made with 13 serotypes identified. Salmonella derby was the predominant serotype and was isolated in shellfish from seven of the 14 stations. Stations which showed the presence of Salmonella in the clam meats covered two general areas,one of which corresponded with the location of high coliform counts in the clam meats as described above. The second area was located along the New York-New Jersey state line, in an area bounded roughly by Seguine Point, Great Kills, Staten Island, N.Y., and Keyport and Keansburg, N.J.

Chemical analyses of meats from shellfish taken from these 50 sampling stations were performed by the Public Health Service's Northeastern Shellfish Sanitation Research Center. The complete report of this agency is contained in Volume III - Appendices of this report. High phenol and mineral oil concentrations were found in shellfish meats taken from a number of stations in the western sector of the Bay, with highest values associated with those stations nearest the mouths of the Arthur Kill and Raritan River. Specific analyses for a number of metals, including copper, chromium, zinc and lead, and for pesticide residues, revealed trace amounts in clam meats.

Pathogen Isolations from Sewage and Bay Waters

In an attempt to further evaluate the effects of Upper Bay and the Narrows on the eastern portion of Raritan Bay, studies were undertaken to isolate Salmonella and Shigella from sewers discharging into the Narrows, and from the waters of Raritan Bay and the Narrows. Isolations obtained are presented in Tables XXII through XXV. Figure 39 identifies the location of those sampling points where Salmonella isolations were successful.

No isolations could be made of Shigella organisms but a number of positive results were obtained for Salmonella. From October 1963 through April 1964, these organisms were isolated in four of seven samples taken from the Nautilus Street sewer, which discharges raw municipal wastes from Staten Island into Upper Bay just above the Narrows. Between October 1963 and July 1964 a total of 20 samples in the Narrows were analyzed, 40% of which were positive for Salmonella. A total of 15 different serotypes were identified, and as many as seven different serotypes were isolated from one sample.

Areas of Staten Island shore closest to the Narrows showed the greatest frequency of Salmonella isolation. Five of 13 samples taken at South Beach were positive; at Midland Beach two of 14 samples showed Salmonella. No Salmonella were recovered from samples further west at the Miller Field beach areas. Some of the same serotypes found in the Narrows were isolated from the bathing area samples. Although a limited number of samples were analyzed, the relatively small sample volume (2 liters) which was used for these determinations suggest a substantial density in these areas.

Attempts were made to isolate Salmonella from various locations in eastern Raritan Bay (See Figure 39) extending on a line from the Narrows southerly towards Sandy Hook. Of the 16 stations sampled, 10 were positive. Of the 48 samples processed, 27% contained Salmonella, and a total of 25 Salmonella isolations were made. S. derby was the predominant serotype, being isolated on eight different occasions, and was also the predominant serotype in the samples collected at the Narrows. Salmonella were isolated below the Narrows as far as No. 10 Bell, approximately six miles south of the Verrazzano-Narrows Bridge.

TABLE XXII

SALMONELLA ISOLATED FROM THE NAUTILUS STREET PIPE DISCHARGING RAW SEWAGE INTO THE NARROWS

Date	*Salmonella* Serotypes Isolated (Gauze-Pad Technic)
16 October 1963	*Salmonella cubana*
4 November 1963	Negative
17 March 1964	Negative
23 March 1964	*S. derby*
	S. bredeney
31 March 1964	*S. derby*
13 April 1964	Negative
21 April 1964	*S. bredeney*

TABLE XXIII

SALMONELLA ISOLATED FROM THE NARROWS IN THE AREA OF THE NAUTILUS STREET OUTFALL

Date	*Salmonella* Serotypes Isolated
16 October 1963	+ Negative
25 October 1963	Negative
28 October 1963	Negative
4 November 1963	Negative
10 February 1964	*S. typhimurium*
	S. livingstone
	S. derby
2 March 1964	*S. tennessee*
3 March 1964	*S. montevideo*
	S. heidelberg
11 March 1964	*S. montevideo*
	S. enteriditis
	S. oranienburg
	S. derby
17 March 1964	S. 6,7: mm-motile (variant)
	S. 6,7: K monophosic (variant)
23 March 1964	*S. derby*
	S. java
	S. oranienburg
	S. bredeney
	S. typhimurium

TABLE XXIII (Cont.)

SALMONELLA ISOLATED FROM THE NARROWS IN THE AREA OF NAUTILUS STREET OUTFALL

Date	*Salmonella* Serotypes Isolated
	S. infantis
	S. anatum
31 March 1964	*S. muenchen*
	S. infantis
13 April 1964	Negative
21 April 1964	*S. heidelberg*
	S. montevideo
	S. oranienburg
8 June 1964	x Negative
10 June 1964	Negative
15 June 1964	Negative
20 June 1964	Negative
26 June 1964	Negative
7 July 1964	Negative
15 July 1964	Negative

+ = Samples from 16 October 1963 to 21 April 1964 were collected by the gauze-pad technique.

x = From 8 June 1964 to 15 July 1964 samples were processed by filtering 2 liters of sample water through diatomaceous earth.

TABLE XXIV

RESULTS OF BACTERIOLOGICAL ANALYSES PERFORMED ON SAMPLES COLLECTED AT SOUTH BEACH, MIDLAND BEACH, AND MILLER FIELD BEACH, STATEN ISLAND

Sample Station (See Fig.39 for Location)	Date	x Salmonella Isolates	MPN/100 ml Coliforms	MPN/100 ml Fecal Coli.
South Beach 1 (Ocean Ave.) 15 ft. from shore	28 July 1964	Negative	7,900	4,900
	4 Aug 1964	*S. st. paul*	4,900	2,300
	10 Aug 1964	Negative	17,000	7,900
South Beach 1 200 ft. from shore	16 July 1964	*S. st. paul*	49,000	3,300
	28 July 1964	Negative	24,000	4,900
	4 Aug 1964	*S. montevideo*	168,000+	7,900
	10 Aug 1964	Negative	17,000	11,000
South Beach 2 (Center of Beachland Lane) 15 ft. from shore	28 July 1964	Negative	3,300	790
	4 Aug 1964	Negative	11,000	630
	10 Aug 1964	Negative	17,000	13,000
South Beach 2 200 ft. from shore	28 July 1964	Negative	4,900	1,700
	4 Aug 1964	*S. st. paul*	7,900	1,400
	10 Aug 1964	*S. montevideo*	13,000	4,900
Midland Beach 1 (Graham Blvd.) 15 ft. from shore	24 July 1964	Negative	9,200	4,600
	28 July 1964	Negative	330	33
	4 Aug 1964	Negative	330	330
	10 Aug 1964	Negative	9,200	5,400
Midland Beach 1 200 ft. from shore	16 July 1964	Negative	-	-
	28 July 1964	Negative	230	50
	4 Aug 1964	*S. st. paul*	16,000	9,200
	10 Aug 1964	Negative	4,900	490

TABLE XXIV (Cont.)

RESULTS OF BACTERIOLOGICAL ANALYSES PERFORMED ON SAMPLES COLLECTED AT SOUTH BEACH, MIDLAND BEACH, AND MILLER FIELD BEACH, STATEN ISLAND

Sample Station (See Fig. 39 for Location)	Date	x Salmonella Isolates	MPN/100 ml Coliforms	MPN/100 ml Fecal Coli.
Midland Beach 2				
(Midland Ave.)				
15 ft. from shore	28 July 1964	Negative	200	46
	4 Aug 1964	Negative	230	33
	10 Aug 1964	*S. typhimurium*	1,300	490
Midland Beach 2				
200 ft. from shore	28 July 1964	Negative	50	20
	4 Aug 1964	Negative	790	330
	10 Aug 1964	Negative	490	330
Miller Field				
Beach 1	24 July 1964	Negative	330	130
2	24 July 1964	Negative	230	33
3	24 July 1964	Negative	330	49
4	24 July 1964	Negative	490	79

x = For *Salmonella* isolations - 2 liters of sample water were filtered through diatomaceous earth.

+ = greater than

TABLE XXV

RESULTS OF BACTERIOLOGICAL ANALYSES PERFORMED ON SAMPLES COLLECTED IN RARITAN BAY

Station (Navigational Aid)	Date	Salmonella by Gauze Pad	Isolations by Filtration (2L)	MPN/100 ml Coliforms	MPN/100 ml Fecal Col.
23 Bell	18 May '64	-	Negative	-	-
	22 May '64	Negative	-	-	-
	2 June '64	Negative	-	-	-
3 Gong	18 May '64	-	(variant) *S.1,3,19 non-motile*	-	-
	22 May '64	Negative	-	-	-
	2 June '64	*S. derby* *S. montevideo* *S. anatum* *S. litchfield*	-	-	-
19 Can	17 June '64	-	Negative	-	-
	24 June '64	*S. derby*	Negative	-	-
	8 July '64	-	Negative	-	-
19A Bell	18 May '64	-	*S. anatum*	-	-
	22 May '64	Negative	-	-	-
	2 June '64	*S. derby* *S. anatum*	-	-	-
39 B & W Bell (black & white)	18 May '64	-	Negative	-	-
	22 May '64	Negative	-	-	-
	2 June '64	*S. montevideo*	-	-	-
17 Whistle	17 June '64	-	Negative	-	-
	24 June '64	Negative	*S. derby*	-	-
	8 July '64	-	*S. infantis* *S. derby*	-	-
17 Bell	17 June '64	-	Negative	-	-
	24 June '64	Negative	Negative	-	-
	8 July '64	Negative	Negative	-	-
	16 July '64	*S. st. paul*	-	-	-
15 Buoy	17 June '64	-	Negative	-	-
	24 June '64	Negative	Negative	-	-
	1 Sept '64	-	Negative	3,300	340
	11 Sept '64	-	Negative	460	60

TABLE XXV (Cont.)

RESULTS OF BACTERIOLOGICAL ANALYSES PERFORMED ON SAMPLES COLLECTED IN RARITAN BAY

Station (Navigational Aid)	Date	Salmonella by Gauze Pad	Isolations by Filtration(2L)	MPN/100 ml Coliforms	MPN/100 ml Fecal Coli.
	21 Sept '64	-	*S. derby* *S. heidelberg* *S. blockley*	16,000+	16,000
13 Whistle	1 Sept '64	-	Negative	24,000	13,000
	11 Sept '64	-	Negative	490	230
	21 Sept '64	-	*S. derby* *S. st. paul* *S. oranienburg* *S. newport*	5,400	3,500
11 Buoy	1 Sept '64	-	Negative	92,000	54,000
	11 Sept '64	-	Negative	490	230
	21 Sept '64	-	*S. typhimurium*	230	230
10 Bell	1 Sept '64	-	Negative	9,200	3,500
	11 Sept '64	-	Negative	230	79
	21 Sept '64	-	*S. derby* *S. heidelberg* *S. muenchen*	16,000+	9,200
5 Bell	1 Sept '64	-	Negative	790	170
	11 Sept '64	-	Negative	330	170
	21 Sept '64	-	Negative	2,800	1,400
4 Nun	4 Nov '64	-	Negative	490	330
6 Nun	4 Nov '64	-	Negative	1,300	490
8 Nun	4 Nov '64	-	Negative	9,200	2,100
R&B Gong	4 Nov '64	-	Negative	230	11

- = No determination

+ = greater than

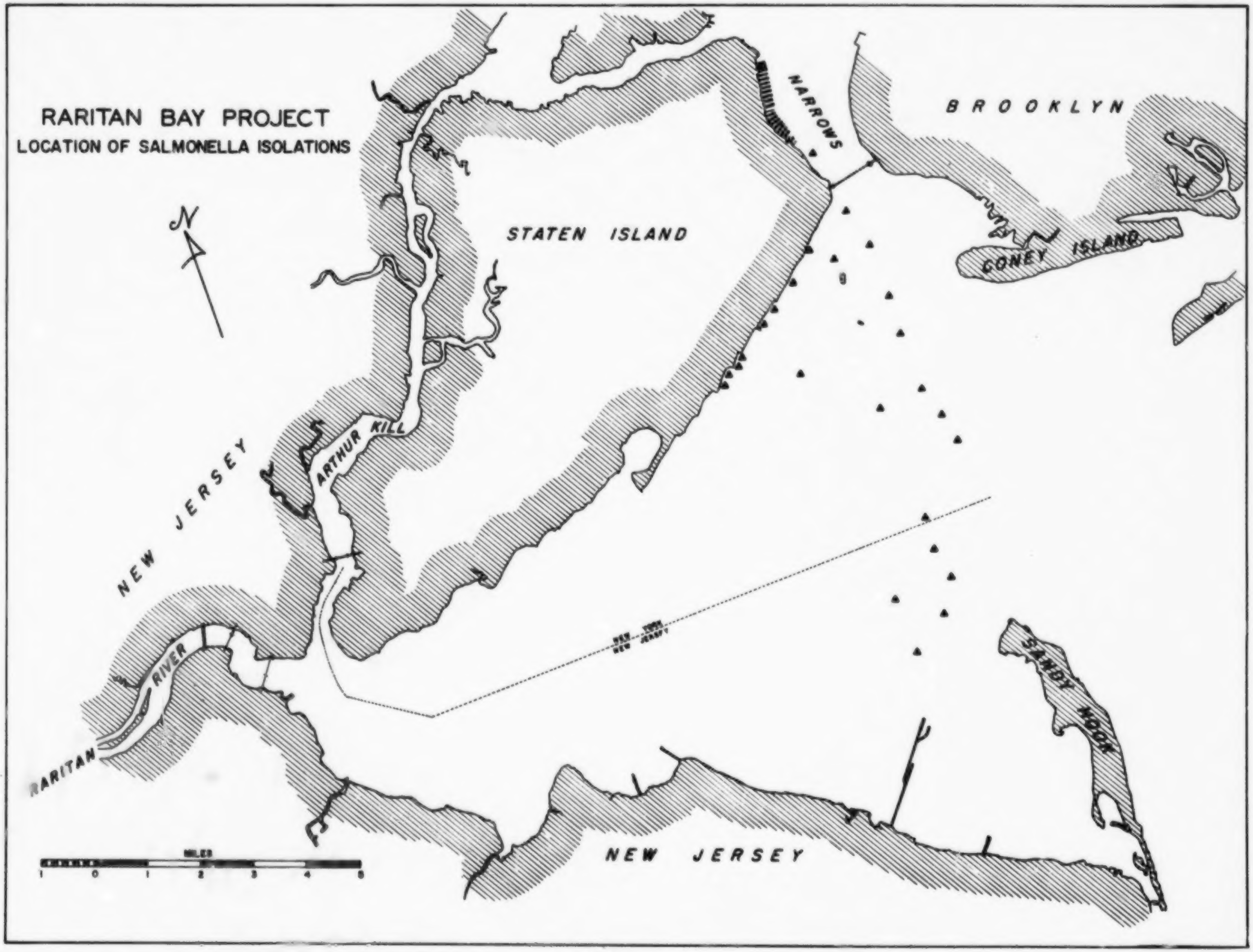

RARITAN BAY PROJECT
LOCATION OF SALMONELLA ISOLATIONS
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
NEW JERSEY
ARTHUR KILL
NEW YORK
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 39

GPO 956-592